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Untersuchung der Rolle von Tätigkeitsspielräumen bei digital vernetzter Arbeit

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LedivA – Projekt „Leistungsregulierung bei digital vernetzter Arbeit“

KMU – kleine und mittelständische Unternehmen

dvA – digital vernetzte Arbeit

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4. Heiden, B., **Zolg, S.,** & Herbig, B. (2022). *Erprobung eines betriebsärztlichen Gesundheitscoachings zur Verbesserung von Gesundheit und Wohlbefinden bei Beschäftigten mit qualifizierter digital vernetzter Arbeit*. In Dokumentation der 62. Wissenschaftlichen Jahrestagung der Deutschen Gesellschaft für Arbeitsmedizin und Umweltmedizin e.V. (DGAUM) (S. 134-138). München: Geschäftsstelle der Deutschen Gesellschaft für Arbeitsmedizin und Umweltmedizin e.V.

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8. Heiden, B., **Zolg, S.,** & Herbig, B. (2022). *Erprobung eines betriebsärztlichen Gesundheitscoachings zur Verbesserung von Gesundheit und Wohlbefinden bei Beschäftigten mit qualifizierter digital vernetzter Arbeit*. Vortrag auf der 62. Wissenschaftlichen Jahrestagung der Deutschen Gesellschaft für Arbeitsmedizin und Umweltmedizin e.V., München, März 2022.
9. Herbig, B**., Zolg, S.,** & Heiden, B. (2022). *Effekte kombinierter verhältnis- und verhaltenspräventiver Maßnahmen auf Belastung und Beanspruchung von Beschäftigten mit digital vernetzter Arbeit – Relevanz von Unternehmensspezifika und Kontext*. Vortrag auf der 62. Wissenschaftlichen Jahrestagung der Deutschen Gesellschaft für Arbeitsmedizin und Umweltmedizin e.V., München, März 2022.
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12. Herbig, B., Heiden, B., & **Zolg, S.** (2023). *Stört digital vernetzte Arbeit die kognitive Leistungsfähigkeit? Ergebnisse einer explorativen Studie zur Veränderung über den Arbeitstag*. Vortrag auf der 63. Wissenschaftlichen Jahrestagung der Deutschen Gesellschaft für Arbeitsmedizin und Umweltmedizin e.V., Jena, März 2023.

13. Herbig, B., Heiden, B., & **Zolg, S.** (2023). *Digital vernetzte Arbeit und kognitive Leistungsfähigkeit. Ergebnisse einer explorativen Studie zur Veränderung über einen Arbeitstag.* Vortrag auf der 13. Tagung der Fachgruppe Arbeits-, Organisations- und Wirtschaftspsychologie und Ingenieurspsychologie der Deutschen Gesellschaft für Psychologie. Kassel, September 2023.

14. Herbig, B., **Zolg, S.**, & Heiden, B. (2024). *Einfluss von Merkmalen arbeitsbezogener Techniknutzung auf Schlafqualität und Schlafstörungen – die Rolle von Menge, Usability, Technikkompetenzen und Technostress*. Vortrag auf der 64. Wissenschaftlichen Jahrestagung der Deutschen Gesellschaft für Arbeitsmedizin und Umweltmedizin e.V., München, März 2024 (angenommen).

Zusammenfassung

Einleitung

Die Digitalisierung hat das Arbeiten verändert. Neue Technologien ermöglichen Formen der Vernetzung, die Auswirkungen auf die Zusammenarbeit von Menschen untereinander und von Menschen mit Maschinen haben. Nachdem Errungenschaften der Informations- und Kommunikationstechnologien zu einer zeit- und ortsunabhängigen vernetzten Arbeit führten, sind nun darüber hinaus weitere Dimensionen einer digital vernetzten Arbeit hinzugekommen. Die Gleichzeitigkeit und Interdependenz von digitalen und analogen Prozessen, der Umgang mit den Eigenlogiken von Technologien sowie die Bewertung von Informationen sind Beispiele für die Zunahme an Komplexität innerhalb dieser Arbeitsform. Beschäftigte sind bei der Bewältigung dieser Arbeit mit einem hohen Maß an kognitiven Anforderungen konfrontiert. Ressourcen, die den Beschäftigten dabei unterstützend dienen sollen, unterliegen jedoch ebenfalls einem Veränderungsprozess. Der Tätigkeitsspielraum als zentrale Ressource wird im Zuge der parallel zur Digitalisierung verlaufenden Subjektivierungsdebatte mitunter als eigene Anforderung bewertet. Ein Zuviel an Tätigkeitsspielraum könnte für die Beschäftigten auch zur (kognitiven) Überforderung führen und sich damit als Stressor erweisen. Vor allem die durch die Veränderungen der modernen Arbeitswelt gestiegenen kognitiven Anforderungen für die Beschäftigten könnten dabei für die Effekte des Tätigkeitsspielraums entscheidend sein. Eine differenzierte Betrachtung dieser Konstellation ist daher notwendig. In dieser Dissertation stehen die Rolle des Tätigkeitsspielraums und mögliche Auswirkungen auf die Gesundheit von Beschäftigten im Rahmen dieser Arbeitsform im Fokus.

Methoden

In einem systematischen Review wird der aktuelle Stand der Forschung zu den spezifischen Arbeitsbedingungen der digital vernetzten Arbeit und damit verbundenen Auswirkungen auf die Gesundheit und das Wohlbefinden der Beschäftigten erarbeitet. Mittels eines Suchstrings wurden sechs Datenbanken nach deutschen und englischen Studien gescreent.

14 Studien aus dem Zeitraum 1981-2019 haben die Einschlusskriterien erfüllt und sind in die Analyse eingeflossen. Die Qualität der Studien wurde mit dem Quality Assessment Tool for Studies with Diverse Design bewertet.

Eine Fragebogenerhebung in drei KMU (n=197) mit anschließender Two-Step-Cluster-Analyse erlaubte die Unterteilung der Beschäftigten in zwei Gruppen. Diese Cluster, Beschäftigte mit hohen und solche mit niedrigen/mittleren kognitiven Anforderungen am Arbeitsplatz, wurden als Moderatorvariable in Regressionsanalysen genutzt, um mögliche moderierte, kurvilineare Effekte von Tätigkeitsspielräumen auf Gesundheitsaspekte zu identifizieren.

Ergebnisse

Die Ergebnisse des systematischen Reviews zeigen, dass Motivation und Zufriedenheit die häufigsten untersuchten Gesundheitsoutcomes sind. Darüber hinaus bestätigen die Ergebnisse die Annahme, dass kognitive Anforderungen bei der Arbeitsform der digital vernetzten Arbeit von zentraler Bedeutung sind. Die Ergebnisse der empirischen Studie zeigen hingegen auch, dass die kognitiven Anforderungen keinen moderierenden Effekt für den Zusammenhang von Tätigkeitsspielraum und diversen Gesundheitsoutcomes haben. Gleichzeitig finden sich sowohl bei den Beschäftigten mit hohen als auch bei denen mit mittleren/niedrigen kognitiven Anforderungen nicht-lineare Zusammenhänge zwischen Tätigkeitsspielräumen und Gesundheitsaspekten. Diese finden sich bei den Burnout-Komponenten Emotionale Erschöpfung und Zynismus sowie am stärksten für Ängstlichkeit.

Schlussfolgerungen

Tätigkeitsspielraum gilt im Hinblick auf die die Gesundheit von Beschäftigten grundsätzlich als Ressource. Die Ergebnisse der vorliegenden Untersuchungen zeigen jedoch, dass es für eine umfassende Analyse weder ausreicht Arbeitsbedingungen und Gesundheitsoutcomes noch digitale Arbeitsmittel isoliert zu betrachten. Um ein vollständiges Bild zu erhalten, müssen sowohl der organisationale als auch der persönliche Kontext berücksichtigt werden.

Summary

Introduction

Digitalization has changed the way we work. New technologies enable forms of networking that have an impact on collaboration between people and between people and machines. After achievements in information and communication technologies led to connected work independent of time and place, further dimensions of digitally connected work have now been added. The simultaneity and interdependence of digital and analog processes, dealing with the inherent logic of technologies and the evaluation of information are examples of the increasing complexity of this form of work. Employees are confronted with a high level of cognitive demands when coping with this type of work. However, resources that are intended to support employees in this are also subject to a process of change. In the course of the debate on subjectivation, which runs parallel to digitalization, autonomy as a central resource is sometimes seen as a demand. Too much autonomy could also lead to excessive (cognitive) demands for employees and thus prove to be a stressor. In particular, the increased cognitive demands on employees due to the changes in the modern world of work can be decisive for the effects of autonomy. A differentiated view of this constellation is therefore necessary. This dissertation focuses on the role of autonomy and possible effects on the health of employees in the context of this form of work.

Methods

In a systematic review, the current state of research on the specific working conditions of digitally connected work and the associated effects on the health and well-being of employees is compiled. Six databases were screened for German and English studies using a search string. 14 studies from the period 1981-2019 met the inclusion criteria and were included in the analysis. The quality of the studies was assessed using the Quality Assessment Tool for Studies with Diverse Design.

A questionnaire survey in three SMEs (n=197) with subsequent two-step cluster analysis allowed the employees to be divided into two groups.

These clusters, employees with high and those with low/medium cognitive demands at work, were used as moderator variables in regression analyses to identify potential moderated, curvilinear effects of job autonomy on health aspects.

Results

The results of the systematic review show that motivation and satisfaction are the most frequently investigated health outcomes. In addition, the results confirm the assumption that cognitive demands are of central importance in the form of digitally connected work. However, the results of the empirical study also show that cognitive demands do not have a moderating effect on the relationship between job autonomy and various health outcomes. At the same time, non-linear associations between autonomy and health outcomes were found for both employees with high and those with medium/low cognitive demands. These were found for the burnout components emotional exhaustion and cynicism, as well as most strongly for anxiety.

Conclusions

Autonomy is generally regarded as a resource with regard to the health of employees. However, the results of the present study show that it is not sufficient for a comprehensive analysis to consider working conditions and health outcomes or digital work tools and materials in isolation. In order to obtain a complete picture, both the organizational and the personal context must be taken into account.

1. Einleitung

1.1 Digital vernetzte Arbeit

Big Data und Künstliche Intelligenz sind Themen, die Wissenschaft und Gesellschaft im Kontext der Digitalisierung derzeit stark beschäftigen (Burmeister et al., 2019, Tisch und Wischniewski, 2022), und von denen erwartet wird, dass sie zu weiteren elementaren Umbrüchen in der Arbeitswelt führen werden. Seit Beginn der Industrialisierung haben technische Errungenschaften die menschliche Arbeit in ihren Prozessen und Anforderungen auf organisationaler und individueller Ebene kontinuierlich verändert (Dery et al., 2017; Attaran et al., 2019; s. Übersicht: Oztemel und Gursev, 2020). Eine zentrale Rolle nahm dabei die Entwicklung der Informations- und Kommunikationstechnologien ein, die mit deutlichen Veränderungen im Bereich der Kooperation und Kollaboration von Beschäftigten einhergingen, unter anderem den Möglichkeiten einer orts- und zeitunabhängigen Zusammenarbeit (Axtell et al., 2004; Antoni und Syrek, 2017). Die weiteren Phasen von Computerisierung über Automatisierung bis hin zur Digitalisierung setzten eine Entwicklung in Gang, die zu einer neuen Form des Zusammenwirkens von Mensch und Maschine im Arbeitsprozess geführt hat: der digital vernetzten Arbeit. Neben den veränderten Möglichkeiten der Informationsverarbeitung, des Informationsaustauschs und -zugriffs spielen dabei autonome, selbstregulierende technische Systeme eine zentrale Rolle (bspw. cyber-physische-Systeme). Davon ausgehend findet Vernetzung nicht länger nur zwischen Menschen bzw. zwischen Menschen und Maschinen statt, sondern auch – „Mensch-unabhängig" – zwischen Technologien. Innovative Technologien werden im Arbeitssystem zu neuen „Teammitgliedern" (Redden et al., 2014), deren mitunter komplexe Eigenlogiken und -dynamiken der Mensch in sein Arbeitshandeln integrieren muss. So wird „menschliches Handeln mit dem eigenlogischen Wirken digitaler Technologien verschränkt" (Heinlein et al., 2023a, S.30), wodurch sich insbesondere die Schnittstellen verändern. Die Beschäftigten stellt das vor die Herausforderung jene Schnittstellen zu managen, d.h. die dort aufeinandertreffenden, unterschiedlichen Logiken sowie Anforderungen von Menschen, Arbeitsbereichen und technischen Systemen zu verstehen und anschließend sinnvoll zu koordinieren und integrieren.

Die Vielzahl der Akteure, neue Wechselwirkungen und Abhängigkeiten sowie die Dynamik der Prozesse stellen die Beschäftigten in ihrer Komplexität aktuell vor große Herausforderungen. Arbeitsbedingungen haben sich in ihrer Ausprägung verändert, zum Beispiel hat sich die Arbeitsintensität in Zeit und Umfang erhöht (Korunka und Kubicek, 2013; Boxall und Macky, 2014) und die Dimensionen von kognitiven Anforderungen haben sich ausgeweitet (Meyer und Hünefeld, 2018). Die Herausforderung liegt dabei etwa in der parallelen Bearbeitung von Aufgaben, die viel kognitive Kapazität beansprucht (Rau und Buyken, 2015; Herbig und Heiden, 2023).

Solchen neuen Herausforderungen mit veränderten Belastungen adäquat zu begegnen ist meist mit hohen Beanspruchungen für die Beschäftigten verbunden.

1.2 Konsequenzen digital vernetzter Arbeit für Gesundheit und Leistungsfähigkeit

Der Umgang mit den Arbeitsbedingungen und Anforderungen der digital vernetzten Arbeit hat direkte Konsequenzen auf die Gesundheit und Leistungsfähigkeit von Beschäftigten. In zahlreichen Studien wurde der Einfluss arbeitsbezogener Belastungen auf Beanspruchungen untersucht (Day et al, 2010; s. Übersicht: Smith et al., 1999; Theorell et al., 2015; Theorell et al., 2016). Dominant diskutiert wird im Zusammenhang mit Technologien in der Arbeitswelt der sogenannte Technostress (Tarafdar et al., 2007; Ragu-Nathan et al., 2008, Ayyagari et al., 2011; La Torre et al., 2018; Tarafdar et al., 2019). Dieses Konstrukt, erstmals erwähnt 1982 (Brod,1982; Salazar-Concha et al., 2021), bezieht sich auf jede Form von Distress, der im Zusammenhang mit Informations- und Kommunikationstechnologien auftritt. Der Fokus liegt auf der Interaktion zwischen Technikmerkmalen und dem Individuum. Dabei wird meist weder zwischen Belastung und Beanspruchung unterschieden noch der jeweilige Kontext miteinbezogen (Zolg et al., 2021). Um jedoch die gesundheitlichen Auswirkungen einer hochkomplexen Arbeitsform wie die der digital vernetzten Arbeit zu erfassen, genügt es nicht Technologien uneinheitlich entweder als primären Stressor oder als Ursache anderer Stressoren zu erfassen (Dragano und Lunau, 2020; Zolg et al., 2021).

Technologien verändern oder ersetzen Tätigkeiten. Gerade letzteres kann zu Unsicherheiten und auch Ängsten bezüglich des Arbeitsplatzes führen. Die Veränderung von Tätigkeiten kann sich negativ auf die Gesundheit auswirken. Häufige Unterbrechungen (Baethge und Rigotti, 2013; Puranik et al., 2019) Informationsflut (Eppler und Mengis, 2004; Soucek und Moser, 2010; Graf und Antoni, 2021) und Formen der Arbeitsintensivierung (Boxall und Macky, 2014; Chesley, 2014; Franke, 2015) erzeugen kurzfristig sowohl körperliche Reaktionen wie zum Beispiel erhöhten Blutdruck oder Herzfrequenz als auch psychische Beschwerden wie Anspannung oder Ängstlichkeit (Steptoe und Willemsen, 2004; Nixon et al., 2011; Steptoe und Kivimäki, 2013, Landsbergis et al., 2013). Langfristig können Fehlbeanspruchungen jedoch auch zu manifesten (psycho)somatischen und psychiatrischen Erkrankungen wie beispielsweise Depression (Theorell et al., 2015) führen.

Beanspruchungen können grundsätzlich positiv und für den einzelnen Beschäftigten aktivierend und förderlich sein (Nachreiner und Schultetus, 2002; Demerouti et al., 2012; Schütte, 2021). Gleiches gilt auch für Beanspruchungen, die sich aus der digital vernetzten Arbeit ergeben. Eine strikte Trennung in positive und negative Auswirkungen von digital vernetzter Arbeit ist schwer zu ziehen. Es sind stets Konstellationen und Kombinationen von Arbeitsbedingungen, die ihre Wirkung jeweils entfalten. Die Ambivalenz digital vernetzter Arbeit zeigt sich also nicht nur in den Konsequenzen für Gesundheit und Leistungsfähigkeit, sondern auch in der Bewertung von Arbeitsbedingungen. Dies verdeutlicht beispielsweise die aus der Anwendung von Technologien in vielen Berufen resultierende Möglichkeit der Flexibilisierung von Arbeitszeit- und ort (Adkins und Premeaux, 2014) Sie kann zu einer höheren Zufriedenheit mit der Vereinbarkeit von Arbeits- und Privatleben führen (Shifrin und Michel, 2022), aber aufgrund eines Gefühls der ständigen Erreichbarkeit auch Formen von Erschöpfung und Irritation auslösen (Boswell und Olson-Buchanan, 2007; Barber und Santuzzi, 2015; Rau und Göllner, 2019).

Neben neuen Möglichkeiten und Konstellationen durch digital vernetzte Arbeit kann sich auch die Bedeutung etablierter Arbeitsbedingungen im Kontext neuer Arbeitsformen ändern. Ein wichtiges Beispiel ist hierfür ist die Ressource Tätigkeitspielraum.

1.3 Die Rolle des Tätigkeitsspielraums

Die Möglichkeit Einfluss auf Handlungen oder Entscheidungen zu nehmen, gilt in klassischen Modellen der Arbeitspsychologie als wesentliche Ressource für eine gesundheits- und persönlichkeitsfördernde Arbeitsgestaltung (z.B. Hackman und Oldham, 1976; Karasek, 1979; s. Übersicht: De Lange et al., 2002; De Lange et al., 2003; Bakker und Demerouti, 2007; Häusser et al., 2010). Die begriffliche Vielfalt, ob als Tätigkeitsspielraum, Autonomie oder Freiheitsgrade bezeichnet, spiegelt die Nuancen dieses Konzepts, das grundlegend für die Möglichkeit der Einflussnahme steht. Dieser Vielschichtigkeit wird der Begriff „Tätigkeitsspielraum" gerecht, der in drei Dimensionen unterteilt wird (Ulich, 2011). Dazu zählen der Handlungsspielraum, der Flexibilität und freie Auswahl an Mitteln oder Verfahren erlaubt, der Gestaltungsspielraum mit der Möglichkeit Handlungen selbstständig zu variieren, und der Entscheidungsspielraum mit dem eigenständigen Festlegen neuer Aufgaben und Zielsetzungen (ebd.). Diese Möglichkeiten liegen den Vorstellungen von menschengerechter und persönlichkeitsfördernder Arbeit zugrunde und ordnen Autonomie als ein wesentliches psychologisches Grundbedürfnis ein. Demnach ist Autonomie klassischerweise als Ressource klassifiziert, die als Reserve oder Hilfsmittel das Erreichen von Zielen unterstützt, die persönliche Entwicklung fördert und die negative Wirkung von Stressoren abfedert (Demerouti et al., 2012).

Positive Auswirkungen ausreichender Spielräume (s. Übersicht: Stansfeld und Candy, 2006; Bonde, 2008; Luchman und González-Morales, 2013; Gilbert-Ouimet et al., 2014; Theorell et al., 2015) wurden beispielsweise für Arbeitszufriedenheit, mentaler Gesundheit und Wohlbefinden (Butterworth et al., 2011; Bentley et al., 2015; Cheung et al., 2015) sowie Leistung (Schaufeli et al., 2009) beschrieben. Weitere Forschungsergebnisse zeigen darüber hinaus, dass geringe Spielräume negative gesundheitliche Auswirkungen wie etwa psychische Erkrankungen haben können (Stansfeld und Candy, 2006; Theorell et al., 2015; Bradtke et al., 2016; Rosen, 2016; Too et al., 2020).

In jüngster Zeit scheint die Bewertung von Tätigkeitsspielraum als etwas ausschließlich Positives im Umbruch. Die Errungenschaften der Digitalisierung gehen meist mit erweiterten Steuerungs- und Kontrolloptionen einher, die Basis für grundsätzlich hohe Spielräume sein können (Sichler, 2006). Eine wesentliche gesellschaftliche Begleiterscheinung der modernen Arbeitswelt ist die Individualisierung. Der Einzelne hat die Verantwortung zur Gestaltung seines Privat- aber auch des Arbeitslebens. Diese Entwicklung weist eine ähnliche Ambivalenz auf wie die Digitalisierung an sich. Zum einen liegt in der Steigerung von Optionen und Entscheidungsmöglichkeit eine Freiheit im Handeln begründet, zum anderen erfordert dies ein neues Maß an Selbstregulation und Eigenverantwortung (Heidenreich, 1996; Sichler, 2006). Daraus folgt, dass die individuellen Handlungen in den Fokus geraten (Kleemann et al., 2002). Gestaltung, Koordination und mitunter auch Zielsetzung sowie Ergebnisverantwortung sind in Folge dieser Subjektivierungsdebatte Anforderungen, die an den Einzelnen gestellt werden (Kleemann et al., 2002; Moldaschl und Voß, 2002). Aus der Möglichkeit einen großen Spielraum zu haben, kann so das Muss werden, ihn zu nutzen. Diesem Ansatz folgend kann ein Tätigkeitsspielraum nicht mehr ausschließlich als Ressource betrachtet werden.

Kritische Auseinandersetzungen mit dem Tätigkeitsspielraum basieren meist auf der Idee des Vitamin-Modells (Warr, 1987), und somit auf der Vorstellung, dass der prinzipiell positive Effekt der Autonomie ab einem bestimmten Punkt ein Optimum erreicht oder gar ins Negative kippt. Theoretische Ansätze wie der „Optionsstress“ (Pfaff, 2013) und der „choice overload“ (Schwartz, 2004) sowie das „Too-much-of-a-good-thing“ Konzept (Grant und Schwartz, 2011) versuchen aufzuzeigen, weshalb das für Ressourcen übliche Leitmotiv „je mehr, desto besser“ dieser Argumentation folgend nicht zwingend auch für Autonomie gelten muss. Derartige nicht-lineare Zusammenhänge wurden für emotionale Erschöpfung (De Jonge und Schaufeli, 1998; Rydstedt et al., 2006), Arbeitszufriedenheit (Meyerding, 2015), Depression (Joensuu et al., 2010) Blutdruck (Juvanhol et al., 2018) und Wohlbefinden (Kubicek et al., 2014; Stiglbauer, 2017; Stiglbauer und Kovacs, 2018) nachgewiesen.

Dennoch ist die aktuelle Forschungslage zu dieser Fragestellung inkonsistent (Bonde, 2008; Netterstrøm et al., 2008; Niedhammer et al., 2021). Der grundsätzlichen Annahme folgend, dass der Tätigkeitsspielraum an sich eine Ressource ist, kann vermutet werden, dass die Ursache für nicht-lineare

Zusammenhänge, also negative Auswirkungen eines „Zuviels“ an Spielräumen, in den Wechselwirkungen mit anderen Arbeitsbedingungen begründet liegt. Gründe für unterschiedliche Ergebnisse können also in dem Zusammenspiel mit anderen Faktoren wie organisationalen Anforderungen oder auch individueller Merkmale (Stiglbauer, 2017; Schweden et al., 2019; Clausen et al., 2022) liegen. Darauf deuten Ergebnisse von Studien hin, die den Tätigkeitsspielraum in einer Konstellation mit Komplexität (Chung-Yan, 2010), Qualifikationsniveau (Clausen et al., 2022) oder hoher Arbeitsintensität (Rau et al., 2010) untersuchten und dabei nicht-lineare Zusammenhänge nachweisen konnten.

Ausgehend von gesteigerten kognitiven Anforderungen im Zuge der Digitalisierung der Arbeitswelt (Meyer und Hünefeld, 2018; Zolg et al., 2021) wird in dieser Forschungsarbeit eine Abhängigkeit des positiven Effekts von Tätigkeitsspielraum auf die Gesundheit von der Höhe der kognitiven Anforderungen angenommen. Denn der grundsätzlich positive Effekt von Spielräumen auf die Gesundheit von Beschäftigten könnte durch die Summe an Anforderungen, hohe kognitive Anforderungen durch die Tätigkeit sowie die kognitiven Anforderungen, die benötigt werden, um den Spielraum zu nutzen, abgeschwächt werden (Zolg und Herbig, 2023). Im Umkehrschluss ist in Übereinstimmung mit früheren Forschungsbefunden davon auszugehen, dass bei Beschäftigten mit niedrigen/mittleren kognitiven Anforderungen linear positive Auswirkungen des Tätigkeitsspielraums auf die Gesundheit zu verzeichnen sind (ebd.).

1.4 Das Projekt LedivA

1.4.1 Projektbeschreibung und Ziele

Die Publikationen dieser Dissertation sind eingebettet in das vom BMBF-geförderte Forschungsprojekt „LedivA – Arbeit oberhalb der ‚mentalen Dauerbelastungsgrenze‘. Leistungsregulierung bei qualifizierter digital vernetzter Arbeit“. LedivA ist ein interdisziplinäres Verbundprojekt, an dem das Institut für Sozialwissenschaftliche Forschung (ISF München e.V.), die Forschungseinheit für Sozioökonomie der Arbeits- und Berufswelt der Universität Augsburg, das Institut für Arbeits-, Sozial- und Umweltmedizin der LMU München sowie drei Praxispartnerunternehmen aus Produktion und Dienstleistung beteiligt waren.

Die Studie wurde von der Ethikkommission bei der Medizinischen Fakultät der LMU München genehmigt (ID: 19-430).

Zentrale Forschungsfrage des Projektes war zum einen, wie sich die Anforderungen und Rahmenbedingungen digital vernetzter Arbeit auf die Möglichkeiten der Beschäftigten auswirken, ihre Leistungsverausgabung selbst zu regulieren, zum anderen, inwiefern diese Arbeitsform physische und psychische Belastungen und Beanspruchungen für die Beschäftigten mit sich bringt und welche Strategien diese zur Bewältigung entwickelt haben. Unter der Annahme, dass digital vernetzte Arbeit mit einer dauerhaft hohen mentalen Beanspruchung der Beschäftigten und einer Tendenz zur anhaltenden Ausschöpfung der Höchstleistung einhergeht, lag ein weiterer Schwerpunkt des Projekts darin – in Analogie zur physischen Belastungsgrenze in der Arbeitsmedizin – eine „mentale Dauerbelastungsgrenze“ zu definieren, die die mentale Leistungsfähigkeit limitiert (Herbig und Heiden, 2023).

Ergänzend sollten mit den Praxispartnern verhältnis- und verhaltensbezogene Gestaltungsansätze zur individuellen Leistungsregulierung und Bewältigung kontinuierlich hoher Leistungsintensität bei dieser Arbeitsform entwickelt und erprobt werden. Die gesammelten Erkenntnisse sollten zum einen für Unternehmen in Form einer schriftlichen Handreichung und eines Praxis-Kompasses (Neumer et al., 2023) nutzbar gemacht werden, zum anderen für die weitere wissenschaftliche Bearbeitung in Form von Veröffentlichungen zur Verfügung stehen. Für die betriebsärztliche Betreuung sollten zudem für die Belastungs- und Beanspruchungsanalyse dieser Arbeitsform geeignete physiologische und psychologische Methoden und Verfahren ausgewählt und empfohlen werden („Betriebsärztlicher Instrumentenkoffer“ s. Heiden und Herbig, 2023a) sowie für die Beratung von Beschäftigten ein spezielles betriebsärztlichen Gesundheitscoaching aufgesetzt und erprobt werden (Heiden und Herbig, 2023b).

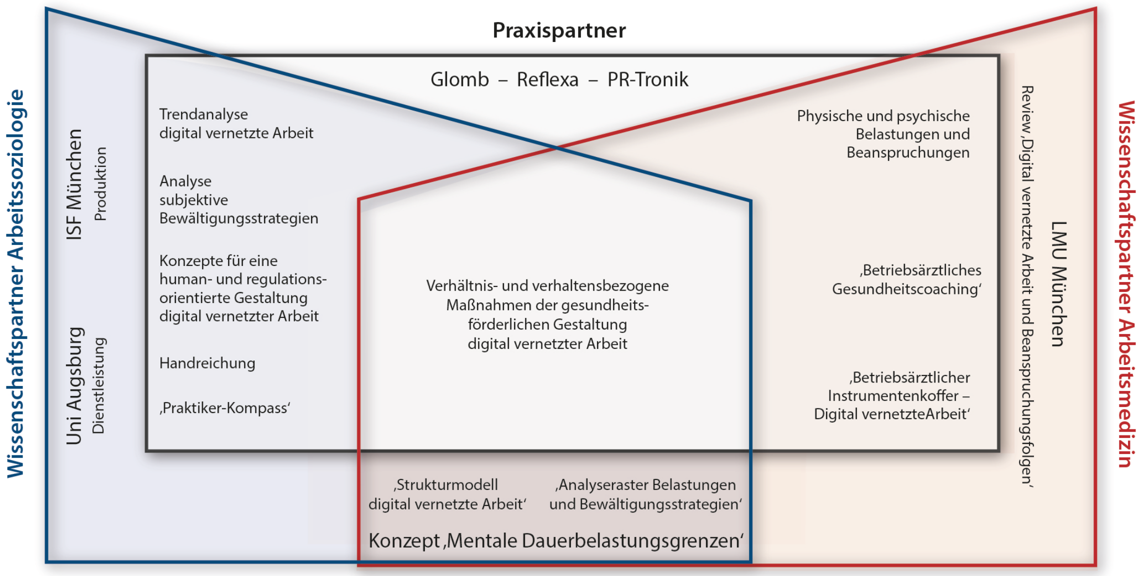

Abb.1: Aufgaben und Zusammenarbeit der Partner im Projekt LedivA (ISF München, 2018, S.17)

Abbildung 1 veranschaulicht die Zuordnung der Projekt(teil)ziele zu den jeweils verantwortlichen Wissenschaftspartnern sowie die Aufgabenteilung und das Zusammenwirken aller Projektpartner im Verbund. Alle zugehörigen Projektergebnisse der Partner sind in Buchform erschienen (Heinlein et al., 2023b).

1.4.2 Studiendesign des Teilprojektes des Instituts für Arbeits-, Sozial- und Umweltmedizin, LMU München

Die Studie wurde in Kooperation mit den drei Unternehmen (Praxispartnern) umgesetzt. Es handelte sich um eine monozentrische, prospektive Interventionsstudie mit insgesamt vier Messzeitpunkten, davon zwei eingebetteten zur spezifischen Interventionsevaluation, die mit gesunden Probanden durchgeführt wurde. Eine Übersicht über das Design gibt die Abbildung 2.

Die Konzeption folgte einem hypothesentestenden Prä-Post-Design mit Entwicklung und Erprobung einer verhaltenspräventiven Intervention für die spezifische Zielgruppe digital vernetzt arbeitender Beschäftigter. Die Erstmessung diente dabei auch zur weiteren Phänomenbeschreibung, die Zweitmessung auch der Bewertung weiterer Veränderungen (durch die Verbundpartner) in den Unternehmen.

Basis des Teilprojekts der LMU war ein systematischer Review (Zolg et al., 2021). Dieser bildet die aktuelle Erkenntnislage aus der deutsch- und englischsprachigen Literatur zum Zusammenhang zwischen digital vernetzter Arbeit und gesundheitsbezogenen Folgen ab.

Anhand einer unternehmensübergreifenden schriftlichen Längsschnitt-Befragung der Beschäftigten aller Partnerunternehmen wurden jeweils zu Beginn und am Ende des Projekts Arbeitsbedingungen, Stressoren und Ressourcen sowie gesundheitliche Beanspruchungsfolgen erhoben. Die Ergebnisse der Ersterhebung erlaubten in einem ersten Schritt eine Spezifizierung von Merkmalen digital vernetzter Arbeit. Im zweiten Schritt wurden von Beschäftigten mit einer hohen Ausprägung dieser Merkmale – und entsprechend einem hohen Anteil digital vernetzter Arbeit – auf freiwilliger Basis im Rahmen einer ärztlichen Untersuchung eine Reihe medizinischer und psychologischer Daten erhoben. Unter anderem wurden Blutdruck und Herzfrequenzvariabilität gemessen sowie neuropsychologische Test durchgeführt, zum Beispiel zur Einschätzung von Veränderungen von Konzentration und Informationsverarbeitung über den Verlauf eines Arbeitstages. Ein (cluster-randomisierter) Teil dieser Beschäftigten erhielt ein betriebsärztliches Gesundheitscoaching (Heiden und Herbig, 2023b), im Rahmen dessen zum einen die aktuelle Gesundheits-, Arbeits- und Lebenssituation reflektiert (inklusive der Untersuchungsergebnisse), zum anderen Ansätze für mögliche Verbesserungen entwickelt und erprobt wurden. Ob dieser erweiterte Beratungsansatz messbare physische und psychische Veränderungen bewirkt hat, wurde nach Abschluss aller Interventionen anhand der Ergebnisse einer zweiten ärztlichen Untersuchung sowie der Zweitbefragung geprüft. Der Zeitpunkt des Beginns der SARS-CoV-2-Pandemie lag jedoch mitten im Projekt LedivA, sodass die Rahmenbedingungen in den Unternehmen und bei den Beschäftigten selbst stark beeinflusst waren. Diese Umstände erforderten Anpassungen auf die Durchführung von Projekt-Maßnahmen. Ein direkter Vergleich zwischen den beiden Erhebungszeitpunkten war aus diesen Gründen schwierig.

In den Befragungen aller Mitarbeitenden zeigten sich zwischen den Messzeitpunkten t1 und t2 unternehmensübergreifend kaum Veränderungen (Heiden und Herbig, 2023a).

Allerdings wurde deutlich, dass bei Beschäftigten, die an mindestens einer Maßnahme des Projektes LedivA teilgenommen hatten, vielfach eine Verschlechterung der gesundheitlichen Outcomes verhindert werden konnte (ebd.). Vorwärtsselektierende Regressionsanalysen über die Zeit zeigten, dass eine Reihe von allgemeinen Arbeitsbedingungen und Charakteristika digital vernetzter Arbeit Beeinträchtigungen des Befindens vorhersagen konnten.

Das betriebsärztliche Gesundheitscoaching wurde kontrolliert randomisiert und auf Basis von Teilnehmerfeedback evaluiert (Heiden und Herbig, 2023b): Im randomisierten Design fanden sich nur tendenzielle Veränderungen, so verbesserten sich in der Coachinggruppe (N=22) im Vergleich zur Kontrollgruppe (N=25) die Durchschlafstörungen und der systolische Blutdruck sank über die Zeit. Im Teilnehmerfeedback gab es eine hohe Zufriedenheit mit dem Coaching, das vor allem in Hinblick auf die Möglichkeit zur Selbstreflexion und Selbststrukturierung als hilfreich bewertet worden (ebd.). Auf Grundlage all dieser Ergebnisse, wurden alle physiologischen und psychologischen Instrumente, die sich im Kontext der digital vernetzten Arbeit als relevant erwiesen haben, gebündelt und in Form des sogenannten „betriebsärztlichen Instrumentenkoffers“ zusammengefasst (Heiden und Herbig, 2023a). Neben Instrumenten und Methoden zur Risikoeinschätzung und Analyse der Belastungen und Beanspruchungen enthält der Koffer auch Handlungsempfehlungen zu Gestaltungsmaßnahmen.

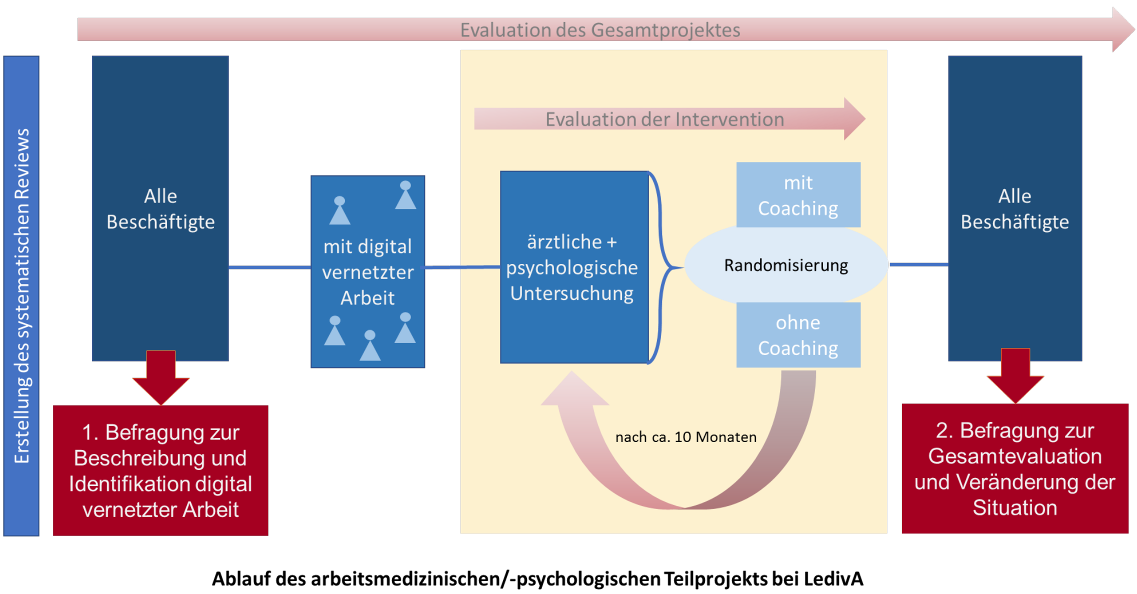

Abb.2 Ablauf des arbeitsmedizinischen/-psychologischen Teilprojekts bei LedivA

1.5 Veröffentlichungen der Dissertation

1.5.1 Fragestellung der Dissertation

Für dieses Forschungsvorhaben, eingebettet in das Projekt LedivA, war von zentralem Interesse, wie sich Tätigkeitsspielraum als primär förderliche Arbeitsbedingung in einer digital vernetzten Arbeitswelt darstellt. Daraus abgeleitet ergaben sich folgende Fragestellungen:

1. Was ist der aktuelle Kenntnisstand der deutsch- und englischsprachigen Forschung zum Zusammenhang von spezifischen Merkmalen digital vernetzter Arbeit und deren Auswirkungen auf die Gesundheit von Beschäftigten?
2. Wie stellt sich das Zusammenwirken spezifischer Arbeitsbedingungen bei digital vernetzter Arbeit dar? Ist ein hoher Tätigkeitsspielraum bei digital vernetzter Arbeit als Ressource zu bewerten oder findet eine Entwicklung hin zum Stressor statt?

Beginnend mit einem systematischen Review, mit dem die grundsätzliche Frage nach den Merkmalen digital vernetzter Arbeit und ihren gesundheitlichen Beanspruchungsfolgen beantwortet und entsprechend der aktuelle Forschungsstand und -bedarf beleuchtet werden sollte, wurde anschließend basierend auf den Ergebnissen dieses Reviews eine Fragebogenuntersuchung entwickelt und durchgeführt. Ziel war es dabei zum einen die psychischen Belastungen und Beanspruchungen der im LedivA-Projekt beteiligten Beschäftigten zu ermitteln und zum anderen Informationen zu den vorherrschenden Anforderungen, insbesondere zu den kognitiven Anforderungen, und dem Tätigkeitsspielraum zu erhalten. Auf diesen Ergebnissen aufbauend wurde dann die Vorgehensweise zur Analyse der zweiten Fragestellung entwickelt.

1.5.2 Zusammenfassungen der Veröffentlichungen in dieser Dissertation

Für Beschäftigte geht die Digitalisierung häufig mit veränderten oder neuen Anforderungen einher, was Einfluss auf deren psychische und physische Gesundheit haben kann.

Formen digital vernetzter Arbeit sind mit Blick auf übergreifende, spezifische Anforderungen an Beschäftigte und daraus resultierende Anforderungen in ihren möglichen gesundheitlichen Auswirkungen noch nicht breit erforscht. Ziel des ersten Forschungsbeitrags (Zolg et al., 2021) im Rahmen der vorliegenden Dissertation war es, diese Lücke zu füllen und den Forschungsstand zum Zusammenhang von digital vernetzter Arbeitsformen und gesundheitlichen Auswirkungen in Form eines präregistrierten systematischen Reviews (PROSPERO No.: CRD42019135431) nach den PRISMA-Schema (Moher et al., 2010) zu erheben.

Die Suchstrategie folgte dem PEO-Schema (Population, Exposure, Outcome). Population war die arbeitende Bevölkerung. Für die Exposition wurden breit gefächert Begriffe gewählt, die das Themenspektrum Digitalisierung und Vernetzung abdecken. So zeichnete sich der Suchstring durch eine Fülle an technologischen Begriffen wie zum Beispiel *cloud computing* oder *big data* aus. Auf Begriffe aus dem Bereich der Informations- und Kommunikationstechnologien wurde hingegen verzichtet, da bereits ausreichende Forschungsbeiträge für diese Form der Arbeit vorliegen und die Fragestellung dieses Reviews einer Definition von digital vernetzter Arbeit zugrunde liegt, die weit über reine Information und Kommunikation hinausreicht. Die Suchbegriffe für die Gesundheitsoutcomes waren so gewählt, dass alle Wohlbefindens- und Gesundheitsauswirkungen, inklusive physiologischer Veränderungen, erfasst wurden. Die Suche wurde nicht auf einen Publikationszeitraum begrenzt. Von insgesamt 19.517 gefundenen Studien aus sechs Datenbanken (Embase, Medline, PsycInfo, PSYNDEX, SocIndex, WISO) wurden nach den Arbeitsschritten des Titel-, Abstract- und Volltextscreenings 14 Studien eingeschlossen (s. Abb.3). Diese 14 Studien wurden zwischen den Jahren 1981 und 2019 publiziert.

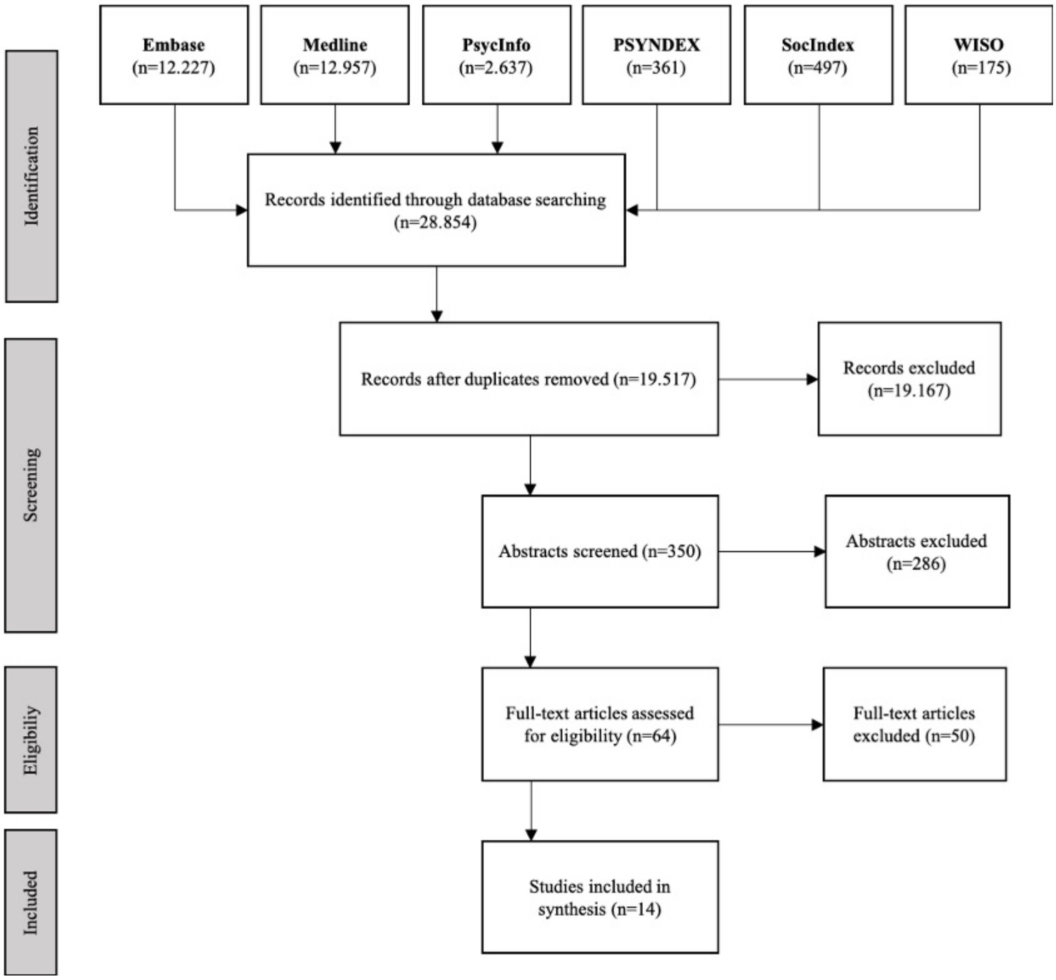

Abb.3 Flow-Chart (Zolg et al., 2021; S.5)

Aufgrund dieser zeitlichen Spannweite, die thematisch von der Einführung der Automatisierung und Computerisierung bis hin zu Digitalisierung reichte, waren die eingeschlossenen Studien sehr heterogen. Die methodische Qualität der Studien wurde mittels des QATSDD (Quality Assessment Tool for Studies with Diverse Design; Sirriyeh et al., 2012) erfasst. Die Studien wurden mit 12 bis 31 Punkten bewertet (M=19.71, SD=4.87), was etwa 27-69% des erreichbaren Maximalwertes entspricht. Die meistgenutzten Erhebungsmethoden waren Fragebögen (n=11), gefolgt von Arbeitsplatzanalysen (n=6) und die Erhebung physiologischer Parameter (n=6) sowie die Durchführung von Interviews (n=5). Eine an den „Empfehlungen für die Durchführung der Gefährdungsbeurteilung psychischer Belastungen“ (European Commission, 1996) orientierte Kategorisierung der betrachteten Arbeitsbedingungen/-anforderungen (kognitive Anforderungen/Arbeitsinhalt, soziale Faktoren, organisationale Faktoren und

Umgebungsfaktoren/Arbeitsmittel), gesundheitlichen Auswirkungen (Motivation/Zufriedenheit, reduziertes Wohlbefinden/affektive Symptome, physiologische Parameter/somatische Beschwerden) und Aktivitätengruppen (Ausmaß von Techniknutzung, Vorher-Nachher Vergleich, Ausmaß von mentalen Anforderungen) ermöglichte es, Zusammenhänge und Wechselwirkungen zwischen diesen Kategorien zu erkennen und zu analysieren. Die Ergebnisse zeigten, dass der übergreifende Fokus dieser Studien auf aus der Arbeit resultierenden kognitiven Anforderungen von Beschäftigten lag. So sind etwa unabhängig vom Grad der Digitalisierung bestimmte kognitive Fähigkeiten und Kompetenzen wie Problemlösen erforderlich. Auch organisationale Faktoren wie Zeitdruck und Workload standen in Zusammenhang mit dem Ausmaß an Techniknutzung (s. Abb.4).

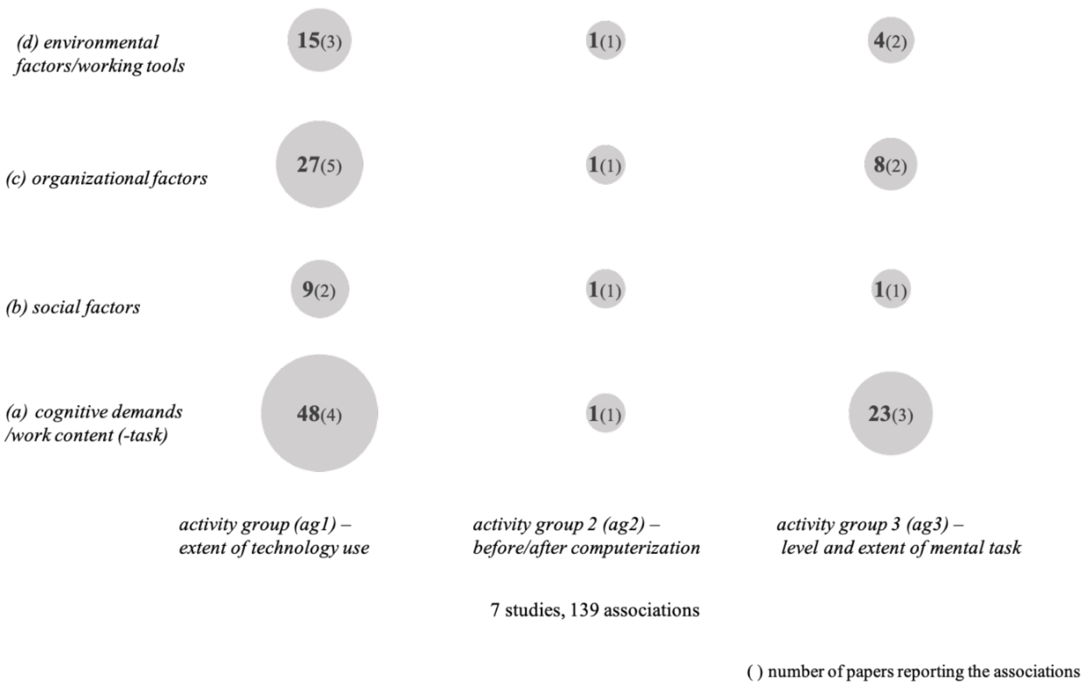

Abb.4 Häufigkeiten der Verknüpfung von Tätigkeitsgruppen und Arbeitsmerkmalen (Zolg et al., 2021; S. 18)

Unabhängig vom Zeitpunkt der Veröffentlichung scheinen klassische Arbeitsbedingungen und etablierte Konzepte wie zum Beispiel das Job-Demand-Control-Modell bei den verschiedenen Betrachtungen von gleichbleibend hoher Relevanz und Aktualität zu sein.

Allein die Anzahl der hier gefundenen Assoziationen von Arbeitsbedingungen, Gesundheitsoutcomes und Tätigkeitsmerkmalen untereinander zeigte die Interdependenzen, die die digital vernetzte Arbeitsform ausmachen. Um diese Komplexität zu erfassen, müssen Analysen über die Erfassung von isolierten Effekten hinausgehen und den gesamten Kontext berücksichtigen.

Weiterer Forschungsbedarf ergibt sich aus den Ergebnissen des Reviews in zwei Handlungsfeldern: Zum einen wurden Kooperation, Kollaboration und weitere Formen der Zusammenarbeit in den eingeschlossenen Studien nur unzureichend thematisiert und sollten detaillierter betrachtet werden. Zum anderen zeigte sich bezüglich der untersuchten Gesundheitsoutcomes in den Studien ein deutliches Ungleichgewicht in der Häufigkeit der Betrachtung physischer und psychischer Beanspruchungen. Studien nach dem Jahr 2000 haben sich vor allem auf die Erhebung eher „weicher" psychischer Faktoren konzentriert und physische / physiologische Merkmale nicht in die Analyse mit einbezogen (s. Abb.5).

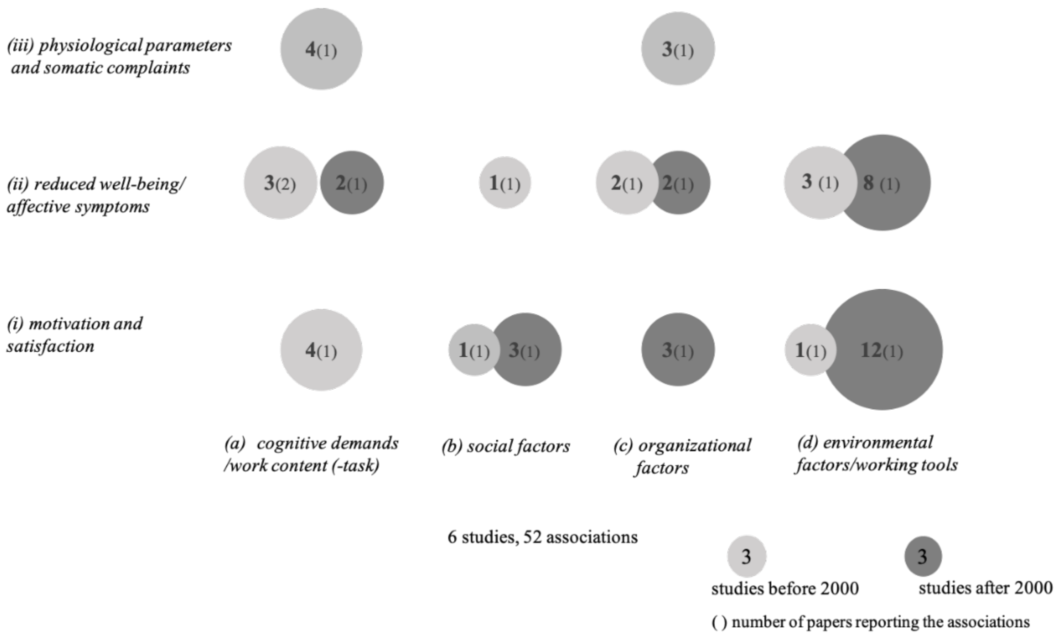

Abb.5 Häufigkeit der Verknüpfung von Arbeitsbedingungen und Gesundheitsoutcomes (Zolg et al., 2021; S. 13)

Bei zukünftigen Untersuchungen wieder mehr Gewicht auf diese Aspekte zu legen, könnte zu neuen Erkenntnisgewinnen führen.

Zumal die Durchführung solcher Studien durch den Einsatz neuester Technologien, wie z.B. moderner Sensortechnologie für die Überwachung von Herzfrequenzen, im Vergleich zu früher deutlich einfacher wäre. Die Rückkehr zu einem Methodenmix, wie er bei den älteren Studien gefunden wurde, würde neue Chancen auf ein detaillierteres Bild des alltäglichen Belastungs- und Beanspruchungsgeschehens bei digital vernetzter Arbeit eröffnen.

Die zweite Publikation analysierte die Rolle des Tätigkeitsspielraums in Abhängigkeit von den kognitiven Anforderungen an Beschäftigte mit digital vernetzter Arbeit (Zolg und Herbig, 2023). Zentral war dabei die Frage, welche Wirkung der Tätigkeitsspielraum unter den Rahmenbedingungen dieser Arbeitsform auf die Gesundheit der Beschäftigten hat, und, ob der Tätigkeitsspielraum auch unter diesen veränderten Voraussetzungen weiterhin als Ressource wirkt. Um Aspekte der Gesundheit, des Wohlbefindens und der Leistungsfähigkeit abzudecken, wurde eine breite Palette an Gesundheitsoutcomes (Burnout: Emotionale Erschöpfung und Zynismus, Maslach und Jackson, 1981; Büssing und Perrar, 1992; Ängstlichkeit, Mohr und Müller, 2014; kognitive Irritation, Mohr et al., 2005; Arbeitsfähigkeit, WAI, Illmarinen, 2007, Tuomi et al., 1998; und Wohlbefinden, WHO, 1998) in die Analyse aufgenommen. Der Tätigkeitsspielraum wurde in den drei Facetten Handlungs-, Gestaltungs-, und Entscheidungsspielraum (TAA; Glaser et al., 2020) erfasst. Die kognitiven Anforderungen wurden aus einer Kombination von sechs Anforderungsmerkmalen, die bei digital vernetzter Arbeit eine Rolle spielen können, operationalisiert: mentale Anforderungen (TAA; Glaser et al., 2020), Wissensanforderungen (COPSOQ, Kristensen et al., 2005), Fertigkeitsvielfalt (WDQ, Morgeson und Humphrey, 2006; dt. Version: Stegmann et al., 2019), Komplexität (ebd.), Problemlösen (ebd.) und Informationsverarbeitung (ebd.). Eine two-step Clusteranalyse dieser Merkmale ermöglichte die Einteilung der Beschäftigten in solche mit niedrigen/mittleren (n=59) und hohen kognitiven Anforderungen (n=134). Zur Analyse möglicher nicht-linearer Zusammenhänge wurden moderierte hierarchische Regressionsanalysen durchgeführt.

Insgesamt konnten 193 Beschäftigte (37,1% Frauen; 60,9% Männer) aus drei KMU mit einem Durchschnittsalter von 41,9 Jahren (19-70, SD=12.6) in die Analyse eingeschlossen werden.

Die Ergebnisse der Korrelationsanalysen zeigten, dass ein positiver Zusammenhang zwischen Anforderungen und Spielräumen vorliegt. Sie bestätigten auch die Annahme, dass größere Spielräume mit positiven Gesundheitseffekten (d.h. positive Korrelationen mit positiven Gesundheitsoutcomes wie Arbeitsfähigkeit und negative Korrelationen mit negativen Outcomes wie Ängstlichkeit) und geringere Spielräume mit negativen Gesundheitseffekten zusammenhängen. Dies spiegelte sich auch in den Ergebnissen der Regressionsanalysen, bei denen positive lineare Effekte des Tätigkeitsspielraums auf die Gesundheitsoutcomes, durchgängig für die Facetten und das Gesamtkonstrukt etwa bei der Arbeitsfähigkeit und dem Wohlbefinden, gefunden wurden.

Für emotionale Erschöpfung, Zynismus und Ängstlichkeit wurden nicht-lineare (umgekehrt U-förmige) Zusammenhänge mit dem Tätigkeitsspielraum gefunden. Am stärksten ausgeprägt waren diese für das Outcome der Ängstlichkeit. Für die Facetten des Handlungs- und Gestaltungsspielraums zeigten sich nicht-lineare Effekte ausschließlich mit der Ängstlichkeit.

Für keines der Gesundheitsoutcomes wurde der Zusammenhang mit Tätigkeitsspielräumen durch kognitive Anforderungen moderiert. Auch konnten keine Haupteffekte der kognitiven Anforderungen nachgewiesen werden.

Durch die Breite der analysierten Gesundheitsoutcomes wurde in den Ergebnissen deutlich, dass eine gesonderte Betrachtung positiver und negativer gesundheitlicher Folgen sinnvoll ist. Die differenziellen Befunde zeigten, dass eine Stärkung von Gesundheit anders zu beurteilen ist als eine Verbesserung von gesundheitlichen Einschränkungen.

Das Fehlen der Moderationseffekte in Kombination mit den gefundenen nicht-linearen Effekten kann in der Einschätzung der Beschäftigten bezüglich der Höhe der kognitiven Anforderungen begründet sein. Grundsätzlich haben die Befragten das Niveau der kognitiven Anforderungen eher als hoch eingestuft. Jedoch weisen beide untersuchten Gruppen übergreifend nicht-lineare Effekte auf, was darauf hindeutet, dass der angenommene Mechanismus einer Form von kognitiver Überforderung bereits auch bei den Beschäftigten auftreten kann, die dem Cluster „niedrige kognitive Anforderungen“ zugeordnet sind.

Die Ergebnisse wurden im Kontext von Qualifizierung und Verantwortung diskutiert. Mangelnde oder fehlende Kenntnisse und Fähigkeiten können davon abhalten vorhandene Spielräume zu nutzen. Die Anforderung die Strukturen, Prozesse und Entscheidungen von Tätigkeiten selbst festzulegen und dabei die Ergebnisse zu verantworten, kann bei Beschäftigten zu negativen Effekten wie Irritation und Ängstlichkeit führen.

1.5.3 Beitrag zu den Veröffentlichungen

Die Beiträge der Autorin (SZ) dieser Dissertation in den beiden Veröffentlichungen werden im Folgenden inklusive der Beiträge der Ko-Autorinnen Dr. Barbara Heiden (BHei) und Prof. Dr. Britta Herbig (BHer) aufgeschlüsselt.

SZ, BHei und BHer entwickelten das methodische Konzept des systematischen Reviews. SZ, BHei und BHer sichteten die Titel und Abstracts der Studien und prüften die Volltexte auf die Einschlusskriterien. SZ und BHei führten die Datenabstraktion aus den eingeschlossenen Artikeln durch, bewerteten die Qualität der Studien und visualisierten die Ergebnisse. SZ verfasste das Manuskript. SZ, BHei und BHer interpretierten die Studienergebnisse und waren an der Überarbeitung des Manuskripts beteiligt. Alle Autoren lasen und genehmigten das endgültige Manuskript des systematischen Reviews.

Für die zweite Publikation entwickelten SZ und BHer die Ideen und die übergreifenden Forschungsziele und konzeptionierten die Methodik. Das Erstellen, Organisieren und Pflegen der Daten erfolgte durch SZ. Die formale Analyse unter Anwendung statistischer, mathematischer, computergestützter oder anderer formaler Techniken zur Analyse oder Synthese der Daten führte SZ durch, BHer supervidierte. Für die Durchführung des Forschungs- und Untersuchungsprozesses, insbesondere die Sammlung der Daten, war SZ zuständig. SZ verfasste das Manuskript. Die Überarbeitung und Redaktion, insbesondere die kritische Durchsicht, Kommentierung oder Überarbeitung, übernahm BHer.

SZ war zudem eng in das Projekt LedivA als eine der Ansprechpartnerinnen für die teilnehmenden Unternehmen und Durchführende der Datenerhebungen eingebunden.

2. Paper I

Zolg, S., Heiden, B., & Herbig, B. (2021). Digitally connected work and its consequences for strain – a systematic review. *Journal of Occupational Medicine and Toxicology, 16*, 42. https://doi.org/10.1186/s12995-021-00333-z.

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Digitally connected work and its consequences for strain – a systematic review

Sabrina Zolg*, Barbara Heiden and Britta Herbig

Abstract

Background: Evolving digitization has an impact not only on the organization of work, but also on the health of employees. Dealing with new technologies, integrating new processes and requirements into work, and restructuring tasks among others are demands that can be stressful and impair health.

Objectives: Our aim was to identify (clusters of) working conditions associated with digitally connected work and to analyze their relations with strain, that is, health and well-being outcomes.

Methods: Between May and October 2019, a search string was used to systematically search six databases (EMBASE, Medline, PSYNDEX, PsycInfo, SocIndex, WISO) for German and English texts according to the PEO scheme. The methodological quality was assessed using the Quality Assessment Tool for Studies with Diverse Design.

Results: 14 studies were identified. Despite the search string containing latest technologies, we identified mostly studies from the 1980s/90s. To aggregate findings, a categorization of work factors (cognitive demands, social factors, organizational factors, environmental factors) and health factors (motivation/satisfaction, reduced well-being/affective symptoms, physiological parameters/somatic complaints) is introduced. The most frequently identified work factors belong to the category of cognitive demands. For health factors, motivation/satisfaction was identified most often. 475 associations were found in total.

Conclusions: This systematic review provides an overview of work and health factors that have been studied between 1981 and 2019. Recent texts frequently study individualized health factors (e.g., life satisfaction) whereas objective physiological measurement data and objective survey methods such as workplace analysis are not used. This latter approach was predominantly found in the older studies. In order to obtain a comprehensive picture, however, it is worthwhile to use a combination of these subjective and objective approaches for future studies in this field.

Keywords: Digitalization, Work, Strain, Systematic review

Introduction

The process of automation and digitization has led and still leads to upheavals in the world of work [6, 124]. Primarily prompted by the changes in information processing, ongoing rapid technological advancements maintain efforts to optimize work organization and increase efficiency as well as rationalization (e.g., [24, 103, 123]). With the rise of the internet and wireless networks the use of information and communication technology (ICT) entered a new level as it became possible to work and collaborate – man with man, as well as man with machine – independent of time and place. Currently, algorithm-based self-learning machines become "teammates" [101] with whom it is imperative to deal [49]. These new technological tools actively shape processes,

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support or replace activities, and enforce or even initiate cooperation [94]. All this has brought about profound changes in the way people work [89].

Work is carried out to an increasing degree in human-machine/human-technology networks which we define in the following as digitally connected work. Such work systems and structures include a large number of players, humans as well as technologies, each following and working in their own logic. They generate a multitude of linkages and interactions as well as various levels of interdependence between these players, and a huge number of simultaneous processes and activities. Thus, work systems like this closely meet definitory criteria of complexity (e.g., [102]). Furthermore, in this kind of digitally connected work, technologies are no longer merely intended to enable and support networking - like in ICT - but also to actively help shape and manage it ([21, 33], see for an overview: [90]). In sum, digitally connected work takes place in human-machine systems which are characterized by digital technologies with inherent logics that can independently and proactively cause interdependencies as well as simultaneities through their interconnectedness with others. However, this can also reduce understandability and manageability of such systems; resulting spontaneous and unexpected „behaviors "can induce a high degree of uncertainty [69, 102].

Numerous studies from work design research (e.g., [11, 25, 63]) show that demands like these can impact strain of employees in the broad sense of short- and longer term somatic, psychological, and behavioral health and well-being (e.g., [50, 67]). Retracing the technical 'evolution' of digital connectivity regarding its consequences for health and well-being of employees, three waves can be identified: first, automatization/computerization and the early use of ICT for information processing; second, communication, flexibilization of work in time and place through internet and mobile networks; and third, the development of integration and networking with new, autonomous "teammates" in widespread networks.

Research on ICT showed changes in work characteristics over time, e.g., characteristics and increasing amounts of information that need to be processed, an acceleration of work processes, increases in work intensity or in system-related interruptions. They are often accompanied by negative strain reactions of employees, e.g., information overload [20, 54], perceived distress or complaints like fatigue, irritation, and emotional exhaustion [10, 27, 43, 45].

Worktime and workplace flexibility through internet and mobile networks led to numerous research on effects of blurring boundaries between work and private life. In this context, strain is often reported as a result of an ambivalence between work demands and individual needs and requirements. Positive effects resulting from a better integration of work and nonwork domains, such as higher work- and life-satisfaction (e.g., [2, 53, 91]), are reported as well as a negative effects, e.g. impaired recovery and exhaustion [35, 104], distress [12, 41, 81, 113], cognitive and emotional irritation, or other health complaints [14, 60], resulting from work-life-conflict or (expected) permanent availability. Independent from research on blurring boundaries, flexible work schedules constantly showed a negative relation to social support and job satisfaction in data from the European working condition survey, but this same survey also showed that a higher frequency of Internet use is positively associated with employees' cooperative and self-improvement behavior, as well as job satisfaction [76]. Cooperation between colleagues can profit from the extension of social networks and knowledge transfer [92], but a decrease in face-to-face contact can also reduce social support (e.g., [8]).

The latest developments in the field of autonomous technologies – relevant for digitally connected work focused in this review – put socio-technical systems and their effects back into focus and revive research on technostress. Originally, the term technostress, coined in 1982 by Brod [18], denoted every experience of distress due to ICT-use without any differentiation between stress and strain or consideration of the context. In the work context it later referred to users' individual characteristics and capabilities to deal with new technologies. A number of so-called "techno-stress" creators (e.g., techno invasion, techno complexity) were introduced and are still used to assess technostress [9, 97, 115]. Dragano et al. [40] and others criticize this as it mixes up different approaches in the consideration of associations between technology and stress. "In some of them, technology is simply an antecedent of other well established work-related stressors like job insecurity or high psychosocial demands whereas in other categories, technology is the primary stressor (e.g., unreliability)" [40]. In view of the increasing variability and complexity of digital and digitally connected systems, we accordingly assume that a more precise focus on work factors and constellations of work factors is necessary for a viable assessment of health risks in such systems, irrespective of the type of activity or attitudes and characteristics of the individual. Additionally, recent reviews on technostress [40, 44, 71, 110] state that most researchers' view on health outcomes is conditioned by those accessible via self-reporting questionnaires like the one introduced by Tarafdar et al. [115], while other outcomes like physiological parameters are rarely ascertained. Irrespective of the diverse approaches, these reviews conclude that technostress can reduce work and life satisfaction as well as performance and has a negative impact on mental health. As one of the scarce physiological findings, an association of increased cortisol level with high levels of technostress was found [106].

Besides technostress, research on "digitization" (in Germany "Industry 4.0"/ "Arbeit 4.0") and related effects on employees' health uses characterizing technologies like cyber physical systems, internet of things, internet of services, augmented manufacturing, robotic etc. [90]. Dependent on the change level, graduations in the complexity of the systems of digitally connected work are found and due to the high number of interrelated socio-technical variables it can be expected that effects on health and well-being might be complex and ambiguous as well (e.g., [116]). In general, research on the impact of these technological changes on health and well-being of employees is still scarce. More often, the transformation is examined considering organizational change or the productivity and effectiveness of work processes (e.g., [24, 103, 123]).

In summary, although a lot of different health related work aspects are known for previous technological developments, a systematic examination of strain-inducing work demands in digitally connected work is missing. As a precondition, work factors and constellations of work factors characteristic for this kind of work need to be identified.

Therefore, the first goal of our systematic review is to provide an overview of (constellations of) working conditions that have been examined in the context of digitally connected working environments so far. The second goal is to consider the influence of these working conditions on the health and well-being of employees. To our knowledge this has not yet been subject of a systematic review. Additionally, the review shall aid to identify the employed occupational health and psychological models as well as research gaps and needs.

Methods

This systematic review was conducted according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines [83]. It was entered in the International Prospective Register of Systematic Reviews (PROSPERO) under the number CRD42019135431 in July 2019 and last updated in January 2020.

Information sources

In total, we searched six electronic databases (EMBASE, Medline, PsycInfo, PSYNDEX, SocIndex, and WISO) for eligible published studies. The search ended on 21 October 2019. No studies were added to the data analysis after this date. There were no restrictions on the publication period. Non-original research such as systematic reviews or conference/discussion papers were not taken into account. There were no further eligible studies identified through a manual search. Studies that were not systematically collected, especially grey literature, were not considered in the analysis.

Search strategy

Our search string was created using the PEO scheme. Population was the working population. Exposure entailed digitally connected work as outlined above. Outcome were strain resp. health effects in general. The operationalization of the search strategy was as follows: we used Mattioli's [79] search strategy for the working population. To cover the exposure, we chose a broad spectrum of technical terms in the context of digitization and networking. A thematic literature search was carried out to add frequently used terms, for example *cloud computing*, *embedded systems* or *big data*. Terms related to ICT were not included in the search string and studies exclusively dealing with these aspects were excluded as reviews on ICT and health are available (e.g., [13]) and as we consider digitally connected work as a development that goes beyond the pure use of ICT. The search terms *well-being*, *health* and *physiolog** for the outcomes were defined to capture all physiological as well as psychosocial health- and well-being-related consequences of strain. The term "technostress" was not included in the search string. As outlined, the concept of technostress but also questionnaires for its measurement mingle stress and strain and therefore do not allow an answer to the objectives of this review. However, assuming that all relevant aspects of stress and strain in that context are covered by the selected exposure and outcome terms, research using technostress in this differentiated manner should be found. For the complete search string see Appendix.

Eligibility assessment

The included studies were selected according to a three-step procedure: 1) removal of duplicates and title screening, 2) abstract- and 3) full text screening. Steps 2 and 3 were carried out by two researchers independently. In case of any disagreement, the abstract or full text was reviewed by a third researcher. Screening results were discussed until agreement was reached. Eligibility criteria were established a priori. Criteria and examples of excluded texts are presented in Table 1.

Data extraction and evaluation

The following data were drawn from the studies: authors and year of publication, country, population (sample size and type of workplace or job task), work factors, research question, outcomes, methods, design, and results. Due to the diverse methods and concepts, no visual

Table 1 Study PEO inclusion and exclusion criteria

Criterion	Inclusion	Exclusion
Population	• working population	• children and youth, students, non-working population(e.g., titles like “Life satisfaction and problematic Internet use: Evidence for gender specific effects”; “Technology-based interventions for preventing and treating substance use among youth”)
Exposure	• digital technologies, work processes in a digital context • influence of technologies on employees	• use of technology for diagnostic purposes (e.g., the use of telemedicine for stroke patients like “Interactive computer-assisted program for cervical liquidbased cytology”) • use of technology for the purpose of teaching/training (e.g., introduction to new radiological technologies like “Integrating Artificial and Human Intelligence: A Partnership for Responsible Innovation in Biomedical Engineering and Medicine” or “The stress and workload of virtual reality training: the effects of presence, immersion and flow”) • focus on the use of information and communication technologies (e.g., “Impact of BYOD on organizational commitment: An empirical investigation”) • focus on the concept of technostress
Outcome	• all health/well-being outcomes in context of digital work factors	• health effects of the used technologies that do not affect the target population (e.g., improvement of schizophrenia patients through therapy applications with virtual reality like “Making monitoring ‘work’: human-machine interaction and patient safety in anesthesia” or “Optimal management of neonatal lung diseases using current technologies”)
Study	• original articles • published in peer-reviewed journals • published in English or German • no limitation of publication date	• other publication types (e.g., conference paper, editorials, project reports, non-original research such as discussion papers/reviews) • other languages

representation of effects or meta-analysis was possible. For this reason, we decided to use a content analysis with a subsequent categorization of the study contents as an evaluation method.

Assessment of methodological quality

The quality of the studies was systematically checked using a tool provided by the University of Leeds, Quality Assessment Tool for Studies with Diverse Design (QATSDD; [112]). This tool is suitable when quantitative, qualitative, and/or mixed methods study designs need to be compared. All studies are evaluated against 16 criteria. The scale ranges from 0 (not at all) and 3 (complete) for each criterion. The quality assessment was done by two raters independently. In the case of disagreement, the relevant evaluation criteria were firstly discussed with a third researcher and then re-evaluated by the two raters. Diverging ratings were discussed between the two raters until consensus was reached. If no agreement could be achieved, a third rater was involved to reach the final evaluation. The interrater reliability between the two raters was assessed by the intraclass coefficient which showed a good to very good agreement (ICC = 0,871).

Results

Study characteristics

In total, 28,854 studies were found. After removal of duplicates ($n = 9337$) and title screening, 350 texts remained for abstract screening. After evaluating the full texts ($n = 64$), 14 studies met the inclusion criteria and were included in this review (flow diagram in Fig. 1).

Table 2 shows the main characteristics and results of the 14 included studies. The sample size of the studies ranges from 10 to 3233 participants. All studies, to varying degrees, dealt with digital or at least technology-mediated working conditions, and investigated these in relation to health outcomes of employees. The oldest study is from 1981 and the most recent one from 2019. Eleven publications were published before the year 2000 and three between 2000 and 2019. The studied samples vary in almost equal proportions between office workers ($n = 4$), production workers ($n = 4$), and various employees ($n = 6$), for example from the banking industry or the service sector. Eleven studies were conducted in Europe, five of them from the former German Democratic Republic (GDR), two in North America and one in New Zealand. There are eight cross-sectional studies and six longitudinal studies. One study used pre-post-measurement. Five studies used a quantitative research design, one a qualitative design, and eight studies chose a mixed-methods approach. The most commonly used measurement method was questionnaires ($n = 11$), followed by work analysis ($n = 6$) and physiological measurements ($n = 6$) and interviews ($n = 5$).

Quality assessment

All studies were evaluated with the QATSDD tool. The reviewed studies scored between 12 and 31 (M = 19.71, SD = 4.87), which represents 27–69% of the achievable maximum value. The ratings of the individual studies are shown in Table 2. On a scale from 0 (“not at all”) to 3 (“complete”), most of the studies gave an almost complete description of the research setting (M = 2.71; SD = 0.45). The objective of the study was also moderately explicitly stated (M = 2.0; SD = 0.96). Both the fit between the stated research question and the method of data collection of the quantitative studies (M = 2.0; SD =

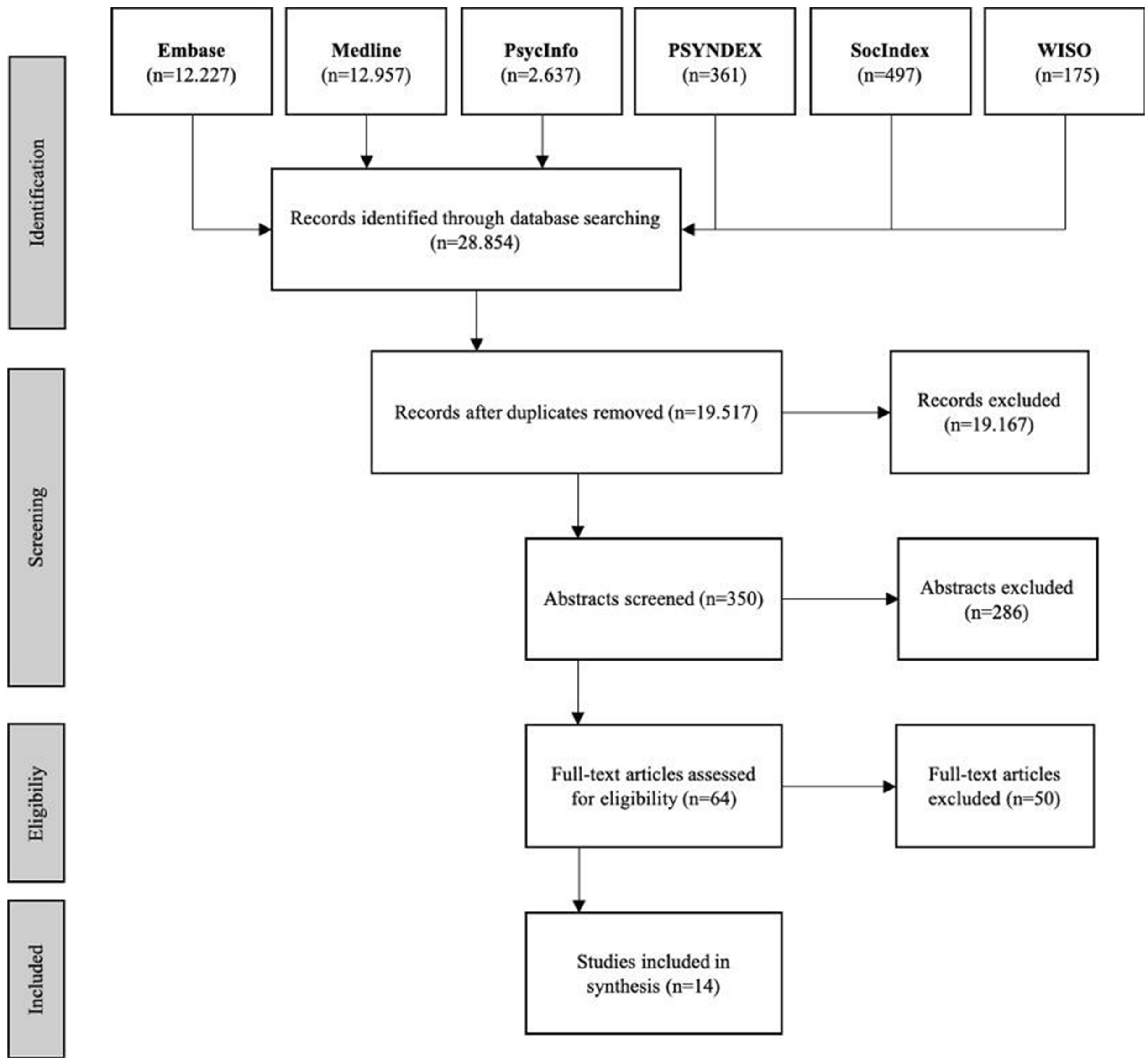

Fig. 1 Flow diagram

0.75) and the fit between research question and method of analysis (M = 2.0; SD = 0.53) moderately met the criteria. In the qualitative methods, the fit between the research question and the format and content of data collection was rather low (M = 1.21; SD = 1.01). A similar assessment was made for the description of an explicit theoretical framework (M = 1.21; SD = 1.25). Criteria of the data collection process (M = 1.92; SD = 0.82) and the rationale for choice of data collection tools (M = 1.5; SD = 0.90) were only very slightly met in most studies. The justification for the selected analytical method was mostly rated between "not at all" and "very slightly" (M = 0.78; SD = 0.67). Criteria for detailed recruitment data were met only slightly (M = 1.07; SD = 0.70). Evidence of sample size considered (M = 0.5; SD = 0.90) and the representativeness of the target group (M = 0.85; SD = 0.86) did not meet the criteria at all. The same applies to the reliability and validity of measurement tools in quantitative studies (M = 0.78; SD = 1.14) as well as to the reliability of the analytical process of qualitative studies (M = 0.35; SD = 0.89). The discussion of strengths and limitations was mostly not mentioned at all (M = 0.71; SD = 0.79). In none of the studies included in the review, information on user involvement in the study design was given.

Table 2 Characteristics of the included studies

First author, publication year, country	Sample, Size	Research Question	Design	Method	QATSDD
[4], The Netherlands	employees of automation sector, $n = 3233$	- analysis of working conditions and career prospects of 32 different occupational groups within automation personnel - identification of the risk factors for stress and strain within these occupational groups - *activity group**: different occupational groups in the automation sector	- quantitative - cross-sectional	- questionnaire (adapted and extended NIPG-Questionnaire; [38])	20
[17], Sweden	"computerized" employees in administration, $n = 42$	- evaluation of work efficiency, work environment, and psychological strain before and after office automation in a participatory project - *activity group*: pre- and post-automation	- mixed - longitudinal (5 separate measures over 1,5 years)	GRID-interview; [48] physiological measurement (blood cortisol, blood pressure) questionnaire (not described; according to the authors with questions about computerization, reorganization, attitudes towards computers, current tasks and beliefs about future tasks, work content, job satisfaction, health/well-being, different symptoms of strain)	19
[19], New Zealand	employees of the service sector, $n = 120$	- analysis of how employees perceive STARA (Smart Technology, Artificial Intelligence, Robotics, and Algorithms)/ job insecurity in relation to their own work and how they prepare for potential changes - analysis whether STARA-awareness/job insecurity is age dependent - analysis what possible effects STARA-awareness/job insecurity has on job and well-being outcomes (the feeling of STARA-Awareness, which "captures the extent to which employees views the likelihood of Smart Technology, Artificial Intelligence, Robotics and Algorithms impacting on their future career prospects" ([19]: p. 241))	- quantitative (plus one open-ended question) - cross-sectional	questionnaire (*career satisfaction*; [55]; *cynicism;* [77]; *depression;* [7]; *job insecurity;* [5]; *organizational commitment;* [82]; *STARA Awareness*; self-developed; *turnover intentions;* [68])	21
[29], Germany (former GDR)	die-casting foundry, $n = 25$	- evaluation of flexible automation solutions compared to conventional production processes with regard to job demands, working conditions, and personality development - analysis of effects on mental well-being and job satisfaction - *activity group:* workers at conventional and flexible automated die-casting machines	- mixed - cross-sectional	interview (self-developed) questionnaire (BMS; [95], questionnaire on satisfaction with work conditions; self-developed; SAA; [1]) work analysis (TBS-K, BPA; [57])	14
[30], UK	employees of computer manufacturing company, $n = 31$	- definition and measurement of advanced manufacturing technologies (AMT) in terms of the concept of coupling; coupling is a construct that describes the degree to which two parts are connected, four variables create this construct: synchronicity, workflow rigidity, method uniformity, and slack. - identification of differences in the working conditions of different AMT-jobs - exploration of the influence of coupling on psychological well-being	- quantitative - cross-sectional	- questionnaire *(coupling:* synchronicity [31, 32]; workflow rigidity, [61]; method uniformity, [118]; Slack, Hickson, [61]; *intrinsic job satisfaction*: "Job itself intrinsic satisfaction" scale, [121]**;** *job complexity:* Perceived Intrinsic Job Charcteristics Scale, [121]**;** *mental health*: version of General Health Questionnaire, [51, 52]; *overall job satisfaction*: Job satisfaction Scale, [121]**;** *supervisory influence,* self-developed**;** *work role* breadth, self-developed)	25
[31, 32], USA	office workers, $n = 121$	- analysis of workers' individual experiences with computers and their	- mixed - longitudinal	- checklist (adapted and extended POMS; [80])	21

Table 2 Characteristics of the included studies *(Continued)*

First author, publication year, country	Sample, Size	Research Question	Design	Method	QATSDD
		attitudes toward different aspects of computer work - identification of the relations of several aspects of work, in particular Video-Display-Terminal-time, and health complaints - *activity group:* employees using VDT (VDT = Video Display Terminal) to varying degrees	(repeated measurements on consecutive days and within one day)	- physiological measurement (optometric screening procedure) - semi-structured interview following the "funnel" technique; [15]	
[58], Germany (former GDR)	administration/ Office, *n* = 240	- assessment and evaluation of VDU (visual display unit) work differing in task-content/−structure and proportion of human-machine interaction - differentiation of effects on motivation and learning opportunities - identification of task characteristics changing due to computer technology and its implementation - identification of effects of these changes on employees - *activity group:* traditional and computer-aided data entry activities with varying degrees of task completeness; activities with human-computer interaction and varying degrees of autonomy	- mixed - cross-sectional	- questionnaire/checklist (AZA; [64], BFB; [62], BMS; [95], SAA; [1]) - work analysis (TBS-GA; [57])	12
[65], Germany (former GDR)	computer screen work activities, *n* = 25	- examination of the relationship between current and long-term effects of stress caused by mental work demands - investigation whether the correlations found can be generalized and whether the consequences of stress are predictable - evaluation of influences beyond work demands (like factors outside the workplace or personal attitudes) - *activity group:* data entry via display terminal; computer-aided ticket sales; computer-aided activity for project planning of organizational processes (problem analysis)	- mixed - longitudinal (annual survey over a period of 3 years)	- interview [105], subjective job evaluation [86] - physiological measurement (e.g., heart rate and blood pressure); occupational health check-up; [122] - questionnaire/checklist (BFB; [62], BMS; [95, 96], EZ-Skala; [87]) - work analysis (occupational science checklist for computer workstations; Schönfelder and Rudolph, [108], psychological work analyses; [78], TBS-GA; [57])	18
[70], Germany	employees in areas with a high level of automation, *n* = 36	- identification of potential stressors occurring with the introduction and use of new technologies in the manufacturing industry	- qualitative - cross-sectional	- semi-structured interview (self-developed)	31
[99], Germany	operators from electric power supply system, *n* = 50	- evaluation of reliability of human operators in highly automated systems using intra- and interindividual differences in physiological and psychological data for the identification of unreliability and action failures - *activity group:* operators in the electroenergy network with the different sub-activities "planned intervention", "monitoring", "fault processing".	- mixed - longitudinal (repeated measurements within one day of examination)	- physiological measures (heart rate, blood pressure) - questionnaire ([98], EZ-Skala; [87]) - work analysis (TBS-GA; [108])	23
[109], Germany (former GDR)	plant operators, *n* = 119	- evaluation and comparison of physical and mental strain during activities in the automotive industry with different levels of automation - *activity group* plant operators in vehicle body construction; plant operators in	- mixed - cross-sectional (physiological measurements repeated in the course of a shift)	- physiological measurements (cardiopulmonary capacity, physical activity, oxygen expenditure, biochemical parameters (e.g., adrenalin), heart rate) - work analysis (occupational science	18

Table 2 Characteristics of the included studies *(Continued)*

First author, publication year, country	Sample, Size	Research Question	Design	Method	QATSDD
		automated final assembly; plant operators in driverless transport systems; assembly workers in body and vehicle final assembly		survey procedure for activity analysis; [107])	
[111], Germany (former GDR)	plant operators at a metal factory, $n = 10$	- evaluation of psychophysical stress and resulting health risks through changes in work content and extended work shifts in automated production processes - *activity group:* early shift 8 h; early shift 12 h; late shift 8 h; late shift 12 h	- mixed - longitudinal (repeated in the course of a shift)	physiological measurements (heart rate) questionnaire/checklist (rating scale), EZ-Skala; [87]) work analysis (workday recording, occupational science survey procedure for activity analysis; [107], objective/subjective stress screening, TBS; Hacker et al., [57])	12
[114], USA/Canada	female clerical workers, $n = 1032$	- examination of the relationship between extent of video display terminal (VDT) use and employees' perceptions of physical work environment, job characteristics and health/well-being - analysis of differences between health symptoms and job characteristics of supervisors and non-supervisors - *activity group*: part-day typist; all-day typist; clerical worker; part-day VDT user; all-day VDT user	- quantitative - cross-sectional	questionnaire (self-developed and according to the author with questions about physical environment, job characteristics, psychological/physical health, and job satisfaction)	20
[117], Sweden	bank employees, $n = 151$	- analysis of bank employees' evaluation of the role of digitization in their daily work - analysis of bank employees' evaluation of the role of digitization and its effects on well-being - exploration of the interaction between digitization and organizational culture (either individualistic or collectivistic) and its effects on well-being - examination of the influence of age, organizational tenure, and position	- quantitative - cross-sectional	- questionnaire *(job satisfaction*: Job Satisfaction Scale; [3]; *life balance*: Affect Balance Scale; [16]; *life satisfaction*: Satisfaction with Life Scale; [37]; *use of digital tools;* self-developed; *organizational culture*: seven-adjectives-Scale; [26]))	22

*activity group – classification within the study according to different activities; further explanation in section *clustering of work factors, health effects and activity groups*; NIPG – Questionnaire on Work and Health (NIPG-TNO; [38]); GRID-Interviews [48]; self-developed – according to the authors; BMS – BeanspruchungsMessSkalen [95, 96], SAA – Fragebogen zur subjektiven Arbeitsanalyse [1], TBS-GA – Tätigkeitsbewertungssystem für geistige Arbeiten [57], BPA – Analyse und Bewertung der persönlichkeitsfördernden Wirkung von Arbeitsaufgaben, POMS – Profile of Mood States [80], AZA – Zufriedenheit mit der Arbeit [64], BFB Beschwerdefragebogen [62], EZ-Skala [87], TBS-GA – Tätigkeitsbewertungssystem für geistige Arbeiten [108]

Clustering of work factors, health effects and activity groups

To summarize the studies, we first clustered all identified working conditions as work factors (independent variables) and outcomes as health factors (dependent variables).

As a basic framework for the clusters of *work factors,* we used the "Recommendations for the implementation of risk assessment of mental stress" (European Commission: Guidance on risk assessment at work, [42]):

a) *Cluster: cognitive demands/work content (task).* This includes demands and working conditions like decision latitude, task variability, or qualification.
b) *Cluster: social factors.* This refers to the social relationships among colleagues and/or superiors, which include, for example, conflicts and support situations, number of contacts, lack of feedback, and leadership.
c) *Cluster: organizational factors*. Organizational factors include mainly the topics working time and workflow (e.g., time pressure/high workload) but also communication and cooperation possibilities of employees (e.g., isolated workstations) as well as information on salary and career opportunities.
d) *Cluster: environmental factors/working tools*. Environmental factors include workplace and work equipment design as well as ergonomic and physical/chemical factors such as light or noise. Working tools incorporate all technologies used. The type of application like the reason for use, for example for information retrieval or for work

optimization, are also included in this cluster. In addition, this term covers not only the devices, applications, and tools themselves, but also effects on the work system as technically caused interruptions and disturbances or, for example, Corbett's coupling term [30].

The majority of studies ($n = 10$) do not use the examination of single work factors as a starting point but constellations of work factors in the context of specific work activities. Thus, it was necessary to set up so-called *activity groups* as a further category of clusters. Three activity groups were aggregated:

– *activity group 1 (ag1):* Extent of technology use, for example display screen activities differentiated by duration of display screen use ($n = 5$) [4, 29, 32, 109, 114]
– *activity group 2 (ag2):* Working conditions before and after automation/computerization ($n = 1$) [17]
– *activity group 3 (ag3):* Level and extent of mental tasks, e.g., "monitoring" vs. "control" activities ($n = 4$) [58, 65, 99, 111].

In the category *health factors,* the following clusters were formed:

i) *Motivation and satisfaction:* Concepts like motivation, organizational commitment, or satisfaction in all their facets as well as turnover intention.
ii) *Reduced well-being/affective symptoms:* Psychological symptoms like irritation and feelings of stress as well as depression and anxiety; fatigue, monotony, and saturation are included.
iii) *Physiological parameters and somatic complaints:* All outcomes of physical examinations such as blood pressure, heart rate or somatic complaints like musculoskeletal or eye symptoms.

Table 3 provides an overview of all work factors and health factors found in the studies, grouped according to these clusters.

Study findings

The main focus in reviewing the included studies was to assess work factors associated with digitally connected work, interrelations of work factors and relationships between work factors and health factors. As not all studies provide statistical evidence or report detailed data, we had to restrict the analysis to frequency counts. In a first step we summarize the total counts for every cluster irrespective of the additional activity groups categorization. Since all work factors or health outcomes associated with digitally connected work are relevant to the research question, all mentions were counted (*cluster (a) cognitive demands / work content (−task)* ($n = 102$), *cluster (d) environmental factors/working tools* ($n = 73$), *cluster (c) organizational factors* ($n = 46$), *cluster (b) social factors* ($n = 17$); *cluster (iii) physiological parameters and somatic complaints* ($n = 72$), *cluster (ii) reduced well-being and affective symptoms* ($n = 30$), *cluster (i) motivation and satisfaction* ($n = 29$)).

After a paragraph on the theoretical framework of the identified studies, we present the number of reported associations between the work factor/activity group clusters and the health clusters aggregated over all studies. Associations that were actually only reported but not described in detail were also included here, as the very combination of two characteristics is interesting in this context. Additionally, tabulated summaries of statistically tested associations in aggregated verbal form are provided. Remarkable single findings are reported following each descriptive section. Results are always reported with their publication date as there is a large time gap between the oldest and most recent publication. The results are described in the corresponding text in descending order according to the counts.

Theoretical framework of identified studies

As the quality assessment shows, the theoretical background is rarely found in the texts and, if so, only briefly addressed. Due to the scope of the review, most studies are rooted in work and organizational psychology. All GDR studies follow the theoretical principles of action regulation theory and pursue the goal of a work design that promotes personality [29, 58, 65, 99, 109]. Hacker and Schönfelder [58], Körner et al. [70] and Stellman et al. [114] substantiate the results with reference to the Job Demand Control Model by Karasek [66]. Brenner et al. [17] based their study on the theory of stress of Lazarus [72] and interpret differences in the expression of stress with different attitudes and other individual factors [73]. They cite the Vitamin model [120] to explain environmental (working) conditions that affect mental health differentially and to varying degrees. To explain the relationship between increased demands and effects on both psychological and physiological stress, they refer to the theoretical principles of Frankenhaeuser [46, 47]. Corbett [30] refers in the interpretation of his results to the theory of Hackman and Oldham [59].

Associations between work factors and health factors

Table 4 shows the associations between work factors and health factors regarding the number of associations with statistical tests and verbally aggregated direction of effects.

Table 3 Focus and key work and health factors

First author, publication year, country	***Main focus of the study***	
	work factors	***health factors***
Andries*, 1991 [4], The Netherlands	Focus: groups of different occupations in the automation sector - differentiation of risk factors for health	
	(a) cognitive demands/work content: challenge of the job (e.g., engaging, offering pleasure), qualification (e.g., education, experience, training), autonomy *(b) social factors:* quality of leadership, contacts with colleagues *(c) organizational factors:* workload (e.g., working hours), hectic working conditions (time pressure, unexpected events), salary and prospects	*(ii) reduced well-being/affective symptoms:* mental strain (e.g., feeling tense, nervous or agitated) *(iii) physiological parameters/somatic complaints:* health complaints, headaches, sleep
Brenner*, 1995 [17], Sweden	Focus: participatory introduction of computerization - changes in working conditions and health effects	
	(a) cognitive demands/work content: qualification, responsibility, task variety, reorganization *(b) social factors:* contacts with fellow-workers and supervisors *(c) organizational factors:* computerization, beliefs about how future tasks would appear, workload *(d) environmental factors/working tools:* computer disturbances	*(ii) reduced well-being/affective symptoms:* mental strain, experience with and attitudes toward computers, nervousness *(iii) physiological parameters/somatic complaints:* somatic symptoms (sleep, heart, fatigue, stomach, musculoskeletal), physiological measures (e.g., cortisol, blood pressure)
[19], New Zealand	Focus: STARA (Smart Technology, Artificial Intelligence, Robotics, and Algorithms)-Awareness - impact on job and well-being outcomes	
	(c) organizational factors: job insecurity/STARA-Awareness	*(i) motivation and satisfaction:* career satisfaction, organizational commitment, turnover intention *(ii) reduced well-being/affective symptoms:* depression, cynicism
Claussner*, 1989 [29], Germany (former GDR)	Focus: different degrees of automation - consequences for health-promoting work design	
	(a) cognitive demands/work content: decision latitude, task variability, transparency, responsibility, cognitive demands *(b) social factors:* social structure (social support, feedback) *(c) organizational factors:* workload (quantitative and qualitative overload), human-machine-division of labor, workflow *(d) environmental factors/working tools:* environmental conditions, usability of technologies	*(i) motivation and satisfaction:* satisfaction with different working conditions (e.g., work design, technical equipment, skill use, division of labor) *(ii) reduced well-being/affective symptoms:* strain, monotony, saturation
[30], UK	Focus: coupling in the context of advanced manufacturing technologies (AMT) - effects on well-being and work demands	
	(a) cognitive demands/work content: job complexity, work role breadth *(b) social factors:* supervisor influence *(d) environmental factors/working tools:* technological coupling (synchronicity, workflow rigidity, method uniformity, slack)	*(i) motivation and satisfaction:* intrinsic job satisfaction, overall job satisfaction *(ii) reduced well-being/affective symptoms:* mental health (e.g., anxiety, depression, low self-esteem)
Dainoff*, 1981 [32], USA	Focus: physical/mental stress and other effects of computer work (e.g., job pressure) as a function of VDT time	
	(a) cognitive demands/work content: task variability *(b) social factors:* quality of leadership, atmosphere with coworkers, customers and supervisors *(c) organizational factors:* pressure, pay, benefits, job insecurity *(d) environmental factors/working tools:* ergonomic comments (e.g., light, noise, temperature, workplace arrangement), interruptions, problems with computer system (e.g., slow response time)	*(ii) reduced well-being/affective symptoms:* mental stress (tension, mental strain), general fatigue (very tired, exhausted, drained after work) *(iii) physiological parameters/somatic complaints:* visual performance (measures of acuity, lateral phoria, and vertical phoria, visual strain (e.g. blurred vision)), physical stress (headaches)
Hacker*, 1985 [58], Germany (former GDR)	Focus: different task-content/–structure and proportion of human-machine interaction in different VDU work associations with task characteristics and strain	
	(a) cognitive demands/work content: autonomy, task variability, transparency, qualification, excessive demands, learning requirements *(c) organizational factors:* cooperation requirements and opportunities, information on hardware/software	*(i) motivation and satisfaction:* job satisfaction, motivation *(ii) reduced well-being/affective symptoms:* psychological complaints, experienced monotony, saturation, stress *(iii) physiological parameters/somatic complaints:* physical complaints
Jackisch*, 1989 [65], Germany (former GDR)	Focus: mental demands during VDU-work - predictability of long-term health effects	
	a) cognitive demands/work content: cognitive demands	*(i) motivation and satisfaction:* job satisfaction, behavioral parameter (e.g., performance) *(ii) reduced well-being/affective symptoms:* current well-being, experienced monotony, saturation, stress *(iii) physiological parameters/somatic complaints:* physiological

Table 3 Focus and key work and health factors *(Continued)*

First author, publication year, country	*Main focus of the study*	
	work factors	***health factors***
		parameters (heart rate and blood pressure), complaints, sick leave
[70], Germany	Focus: human-machine-interaction - stress	
	(a) cognitive demands/work content: deskilling, qualification requirements, situation awareness *(c) organizational factors:* general evaluation of human-machine interaction *(d) environmental factors/working tools:* technical problems (e.g., software/hardware problems) usability (e.g., self-descriptiveness)	*(ii) reduced well-being/affective symptoms:* stress
Rau* (1996) [99], Germany	Focus: human reliability in complex automated systems and associated health effects	
	(a) cognitive demands/work content: responsibility, cognitive demands	*(i) motivation and satisfaction:* motivation *(ii) reduced well-being/affective symptoms:* mental tension, emotional state, locus of control, current intrinsic states (e.g., ready to exert, tensioned, self-assured) *(iii) physiological parameters/somatic complaints:* heart rate, blood pressure
Rutenfranz*, 1989 [109], Germany (former GDR)	Focus: changes in physical, mental, and emotional strain through automation	
	(a) cognitive demands/work content: complexity, responsibility, variability, cognitive demands *(c) organizational factors:* breaks *(d) environmental factors/working tools:* disruptions	*(iii) physiological parameters/somatic complaints:* biochemical parameters (adrenalin/noradrenalin), heart rate, energy expenditure, cardiopulmonary performance (physical examination, bicycle ergometer)
Seibt*, 1988 [111], Germany (former GDR)	Focus: shift work - health effects	
	(a) cognitive demands/work content: task content, action control *(b) social factors:* social integration *(d) environmental factors/working tools:* aggravating conditions (e.g., noise)	*(i) motivation and satisfaction:* readiness to make an effort *(ii) reduced well-being/affective symptoms:* experienced strain (initiative, self-confidence, emotional tension, fatigue) *(iii) physiological parameters/somatic complaints:* heart rate
Stellman*, 1987 [114], USA/Canada	Focus: extent of video display terminal usage - description of job characteristics with analyses of health effects	
	(a) cognitive demands/work content: task variability, decision latitude, repetitious work, understanding of work process, learning new things, work "makes sense", cognitive demands *(c) organizational factors:* workload *(d) environmental factors/working tools:* physical characteristics of the office (e.g., ergonomic stressors, air quality stressors, privacy)	*(i) motivation and satisfaction:* job satisfaction, office satisfaction *(ii) reduced well-being/affective symptoms:* psychological symptoms (irritation, anxiety, depression, hopelessness) *(iii) physiological parameters/somatic complaints:* health symptoms (eye-, musculo-skeletal-, gastrointestinal-, respiratory-symptoms)
[117], Sweden	Focus: perception of digitalization - the effect on subjective well-being of bank employees	
	(b) social factors: organizational culture *(d) environmental factors/working tools:* digitalization (degree of use of digital tools, subjective experiences associated with the use of digital tools)	*(i) motivation and satisfaction:* job satisfaction, life balance, life satisfaction

(*studies categorized by activity group)

Figure 2 presents all associations between work factor clusters and health clusters investigated in the studies irrespective of which part of the publication (results or discussion) they are reported in. The associations also include results from activity group studies if they investigated distinct work and health factors.

Cluster (d) environmental factors/working tools This cluster is most frequently associated with *cluster (i) motivation and satisfaction* with 13 counts. The main focus is on the outcome job satisfaction. All 12 results after 2000 are exclusively found in Umans et al. [117]. They examined each of three outcome variables (job satisfaction, life satisfaction, life balance) with four work factors, which are differentiated by the intended use of digital tools. They found overall significant positive associations; especially the use of digital tools for the purpose of work optimization has a positive relation to all three satisfaction facets. Furthermore, life satisfaction has a significant positive correlation with the use of digital tools for information management. The older study in this context, Corbett [30], described a significant negative influence of coupling on intrinsic job satisfaction.

Table 4 Summary of the associations between work factors and health factors

First Author	*Work factor clusters (iv)*	*Health outcome cluster (dv) Number of reported associations in total**	*Number of reported direct associations with statistical analysis*	*Number of reported associations without statistical analysis*	*Direction of effects***	*Number of reported effects with work/health variables as moderator /mediator/ control*
[30];	Cognitive demands / work content	Motivation and satisfaction (4)	4	0	inconclusive	
[17];		Reduced well-being / affective symptoms (5)	3	2	not significant	
[70]		Physiological parameters and somatic complaints (4)	4	0	significant positive	
[30];	Social factors	Motivation and satisfaction (4)	2	0	not significant	2
[117]		Reduced well-being / affective symptoms (1)	1	0	not significant	
		Physiological parameters and somatic complaints (0)	0	0		
[19],	Organizational factors	Motivation and satisfaction (3)	0	0		3
[32],		Reduced well-being / affective symptoms (4)	2	0	significant positive	2
[17]		Physiological parameters and somatic complaints (3)	3	0	significant positive	
[30];	Environmental factors / working tools	Motivation and satisfaction (13)	13	0	inconclusive	
[117];		Reduced well-being / affective symptoms (11)	3	8	significant positive	
[32], [70]		Physiological parameters and somatic complaints (0)	0	0		

* number of papers represented by the counts: see Fig. 2

** summary assessment independent of underlying construct; significant negative/significant positive = if 75% of reported associations are significant negative/ significant positive and the rest is not significant; all other combinations: inconclusive; not significant = no significant association at all

The second often investigated relationship is this cluster in conjunction with *cluster (ii) reduced well-being/affective symptoms* [30, 32, 70]. Corbett [30] showed a significant positive association between coupling and mental health. In their qualitative interview study, Körner et al. [70] identified a connection between technical interruptions and software, hardware, or usability problems and perceived stress. Dainoff et al. [32] showed that there is a significant positive correlation between VDT-related lighting problems and stress.

In sum, negative (e.g., stress) as well as positive health effects (e.g., job satisfaction) are related with environmental factors and the application of technological tools.

Cluster (a) cognitive demands/work content Relations with *cluster (ii) reduced well-being/affective symptoms* were investigated by three studies [17, 30, 70]. In the Corbett study [30], multiple regression analysis reveals no significant association of job complexity or role breadth with mental health. Brenner et al. [17] show that after computerization, a higher experienced level of job

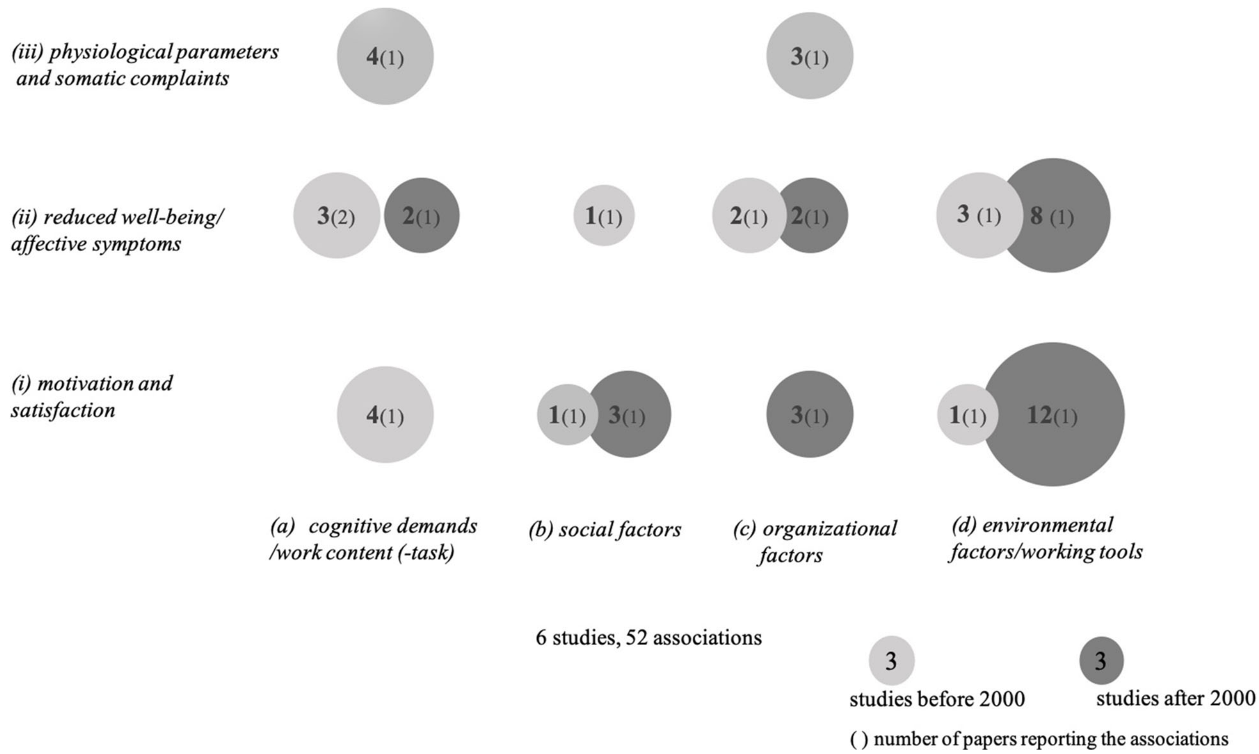

Fig. 2 Frequency of associations between work factors and health factors

qualification is significantly positively correlated to a high frequency of several psychosomatic symptoms like nervous symptoms. Körner et al. [70] point out that insufficient qualification in handling digitalized hard- and software seem to be related to stress.

Relations with *(i) motivation and satisfaction* are only considered by Corbett [30] who shows that job complexity is positively related to overall job satisfaction.

The only study that examined variables in the context of *cluster (iii) physiological parameters and somatic complaints* is Brenner et al. [17]. They report positive associations between qualification, in the sense of more qualified work after automatization, and a high frequency of sleep-, heart-, and fatigue- symptoms.

In sum, *cluster (a) cognitive demands/work content* is dominated by different aspects of qualification. Two studies [17, 70] assume that there is an increased need for qualification when using digital technologies. Insufficient qualification and skills can lead to psychological and physiological stress. The job complexity factor is generally rated positively.

Cluster (c) organizational factors This cluster has most associations with health effects of *cluster (ii) reduced well-being/affective symptoms.* Dainoff et al. [32] report a weak but significant positive correlation between job pressure and mental stress, and also between job pressure and fatigue in the sense of tiredness and exhaustion. Brougham et al. [19] show that when job insecurity is prevalent among employees, there is a positive significant association with depression and cynicism.

Second most frequently reported, in one study, are associations between *cluster (c) organizational factors* and *(iii) physiological parameters and somatic complaints.* Brenner et al. [17] found positive significant correlations between workload and sleep-, heart-, and musculoskeletal symptoms.

Only Brougham et al. [19] investigate outcome variables which are related to *cluster (i) motivation and satisfaction*. They report that the overall perception of job insecurity, in the sense that technology replaces jobs, is low. This is reflected in a significant negative correlation between job insecurity and both organizational commitment and career satisfaction. Consequently, they find a positive significant correlation between job insecurity and turnover intention.

Cluster (b) social factors Variables from *cluster (b) social factors* were the most scarcely considered work factors in the context of health effects [30, 117]. Umans et al. [117] examined the moderating effect of organizational culture on job and life satisfaction and on life balance, all assigned to *cluster (i) motivation and satisfaction*. The only significant effect was found with life balance. A collectivist organizational culture was found to moderate the effect of the use of digital tools for work optimization on life balance. Furthermore, a higher collectivist organizational culture was found to result in a better life balance. In the study by Corbett [30], no significant relationship was found between supervisor influence and different satisfaction variables.

There was also no significant correlation between supervisor influence and mental health in the Corbett study [30], which was assigned to *cluster (ii) reduced well-being/affective symptoms.*

Associations between activity groups and health factors

Table 5 shows the associations between activity groups and health factors regarding the number of associations with statistical tests and verbally aggregated direction of effects.

Figure 3 summarizes all mentioned associations between activity group clusters and health factors irrespective of which part of the publication (results or discussion) they are reported in.

All ten studies with activity groups report associations with health factors (Table 3).

Activity group 1 (ag1) - extent of technology use *(Ag 1)* shows most (43) associations with health outcomes from *cluster (iii) physiological parameters and somatic complaints.* With 25 associations, the study by Dainoff et al. [32] contributes most to this category with the results of a large number of differentiated eye examinations by VDT users. However, they could not find any

Table 5 Summary of the associations between activity groups* and health factors

First author, publication year	*Activity group cluster (iv)*	*Health outcome cluster (dv) Number of reported associations in total***	*Number of reported direct associations with statistical analysis*	*Number of reported associations without statistical analysis*	*Direction of effects ****	*Number of reported effects with work/health variables as moderator /mediator/ control*
[4, 29]; [109]; [114]	activity group 1 (extent of technology use)	Motivation and satisfaction (12)	11	1	inconclusive	0
		Reduced well-being / affective symptoms (9)	2	7	not significant	0
		Physiological parameters and somatic complaints (43)	34	9	significant positive	0
[17]	activity group 2 (before and after automation/ computerization)	Motivation and satisfaction (0)	0	0		0
		Reduced well-being / affective symptoms (1)	1	0	not significant	0
		Physiological parameters and somatic complaints (6)	6	0	significant positive	0
[58, 65, 99 111]	activity group 3 (level and extent of mental tasks)	Motivation and satisfaction (7)	3	4	inconclusive	0
		Reduced well-being / affective symptoms (11)	8	3	significant positive	0
		Physiological parameters and somatic complaints (8)	4	4	significant positive	0

* this table refers to group comparisons and the association was reported with the group with the highest extent of technology use, the group after automation, or the group with the highest level of mental tasks
** number of papers represented by the counts: see Fig. 3
*** summary assessment independent of underlying construct; significant negative/significant positive = if 75% of reported associations are significant negative/ significant positive and the rest is not significant; all other combinations: inconclusive; not significant = no significant association at all

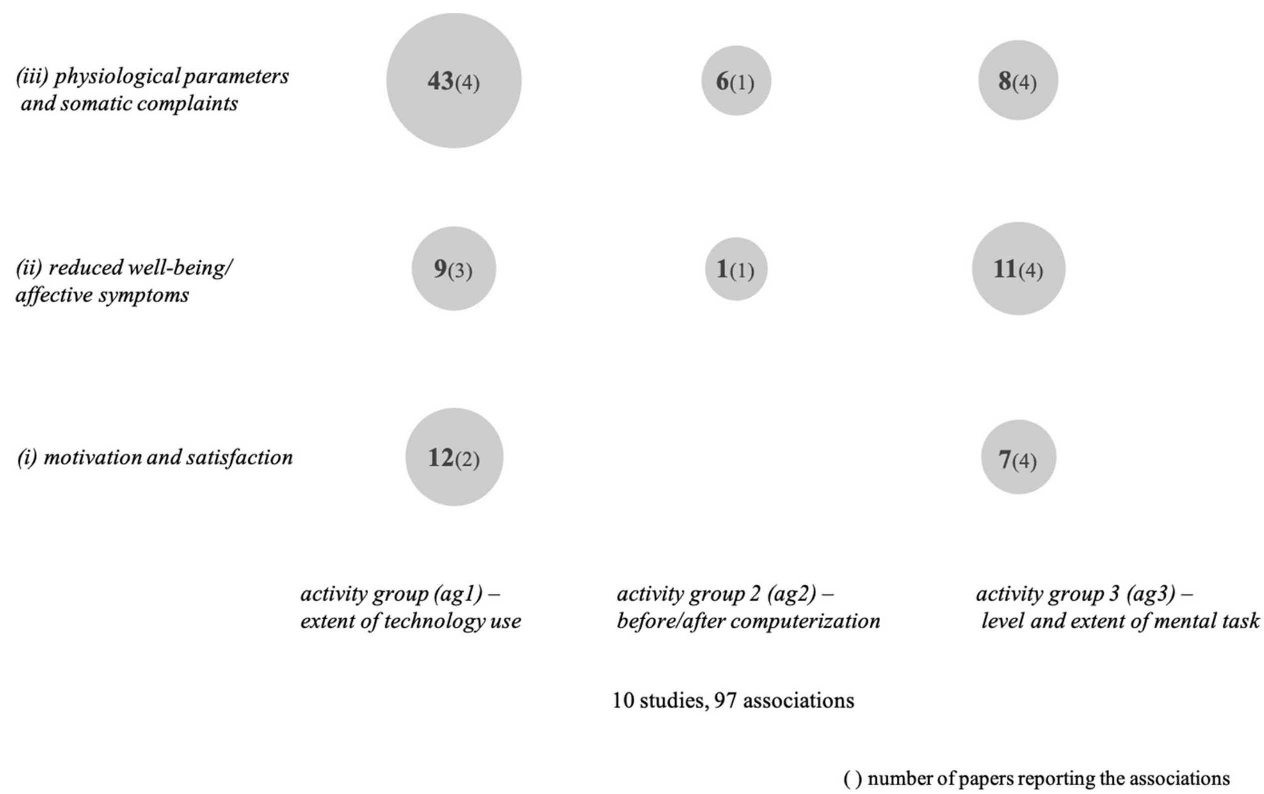

Fig. 3 Frequency of associations between activity groups and health factors

significant effects depending on time of day. Visual symptoms were also examined in the study by Stellman et al. [114]. They show that those who work full-time on a PC have increased eye complaints. Considering other somatic symptoms such as gastrointestinal or respiratory symptoms, no differences could be observed with respect to varying degrees of technology use. Rutenfranz et al. [109] show that those who use automated tools the most have both a higher heart rate and higher blood pressure.

With 5 out of 9 associations, *cluster (ii) reduced well-being/affective symptoms* is characterized by the study of Andries et al. [4] who found that workers in middle management occupations in the automation sector often feel tense and that occupations with a demanding and responsible character often feel agitated. Dainoff et al. [32] show that the correlation between VDT-time and extent of stress is low and not statistically significant.

Cluster (i) motivation and satisfaction is dominated by the outcome job satisfaction. Claussner and Müller [29] report that work at automated machines is associated with higher satisfaction with mental and physical demands. Stellman et al. [114] found that job satisfaction among all-day VDT-users was lower compared to part-day VDT-users. Satisfaction with the office and the environment was very high among all-day VDT-users and lower among part-day VDT-users and part-day typists.

In sum, these associations highlight the fact that the extent of technology has a significant impact on the mental and physical health of employees.

Activity group 2 (ag2) - before/after computerization The measurements for *(ag2)* [17] after computerization further show a positive association between workload and the frequency of sleep-, heart-, and fatigue-symptoms as well as with nervous symptoms, that is, after computerization nervous and fatigue symptoms were higher than before. Additionally, they found increased cortisol levels during the introduction of computerization but conclude that this was rather an (early) effect of activation due to job enrichment than of negative stress.

Activity group 3 (ag3) - level and extent of mental task In *(ag3)*, all three health clusters are researched almost to an equal extent by all four papers [58, 65, 99, 111]. The focus of *cluster (ii) reduced well-being/affective symptoms* is on fatigue, monotony, and saturation. Hacker and Schönfelder [58] show that in activity groups with less challenging work contents, the values of fatigue and saturation range in scores that indicate persistently reduced work efficiency. In a longitudinal assessment, Jackisch et al. [65] found that differences in (health-

)effects of strain (including fatigue, monotony, saturation) are activity-specific. Nevertheless, the longitudinal analysis also showed that not one single factor but a multifactorial set of conditions is causative for long-term effects of strain. Rau [99] shows that the level of demand of the activity is essential for the judgement of the emotional condition. This is more negative if the highest demand level is present. This group also reports lower feelings of control.

In *cluster (i) motivation and satisfaction,* Hacker and Schönfelder [58] find that satisfaction with the task and qualification is lower in activity groups with less challenging work content. Nevertheless, the activity group with the most challenging work content (managers) reports very low satisfaction with both the tasks and the demands. Hacker and Schönfelder [58] attribute this to a very high level of responsibility and time pressure associated with this activity group. Seibt et al. [111] show a decrease in work engagement only for the activity group with an extended morning work-shift.

Variables of *cluster (iii) physiological parameters and somatic complaints* were mainly heart rate and blood pressure measurements and physical complaints. Hacker and Schönfelder [58] report psychophysical results only for one activity group. They observed statistically significant fewer complaints in the activity group with a more challenging work content. Rau [99] proved that differences in heart rate and blood pressure were associated with the requirement level of the individual activity. Activities that dealt with malfunctions or performed interventions were associated with significantly higher blood pressure and heart rates than monitoring activities. Seibt et al. [111] found no statistically significant correlation between activity groups and heart rate concerning duration of the activity and time of the day. Jackisch et al. [65] report aggregated data; blood pressure and somatic complaints are parameters from the set they used to differentiate the effects of strain (see associations with *cluster ii*).

In sum, results suggest that the most complex activities are reflected in the highest values of psychophysiological values such as heart rate, blood pressure and lesser emotional well-being.

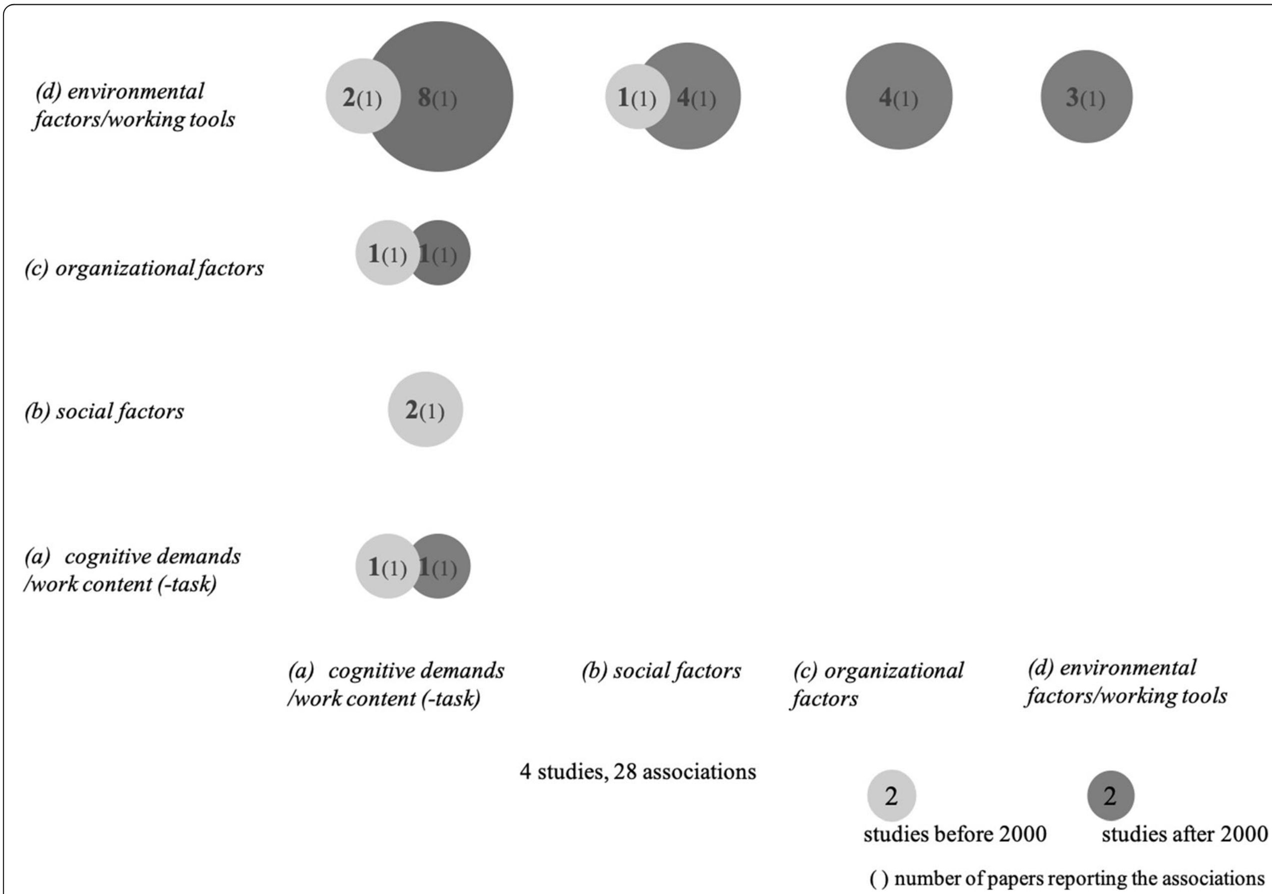

Fig. 4 Frequency of interrelations between work factors

Interrelation of work factors and associations with activity groups

Figure 4 summarizes the interrelations between the work factor clusters including results from activity group studies if they investigated interrelations between distinct work factors.

Cluster (d) environmental factors/working tools Associations with *cluster (a) cognitive demands/work content (−task)* are considered most often. Körner et al. [70] conclude from the analysis of their interviews that human-machine interaction can lead to many positive effects resulting from the acceleration of work processes, more precision in the manufacturing process and the reduction of undetected errors. They also point out that frequently changing and more and more complex systems demand intensified qualification. Corbett [30] examined the work factors job complexity and role breadth, both assigned to *cluster (a) cognitive demands/ work content (−task)*, in connection with coupling and did not find significant associations. For associations with *cluster (b) social factors*, Corbett [30] shows a positive significant correlation between supervisor influence and coupling. Umans et al. [117], who used organizational culture as a moderation variable, demonstrate that a higher degree of a collectivist organizational culture improves the relationship between the use of digital tools for work optimization and life balance.

Associations between *clusters (d) environmental factors/working tools* and *(c) organizational factors* and within *(d) environmental factors/working tools* were investigated only by Körner et al. [70]. They conclude that time pressure is often related to technical problems and hard- and software problems and that interdependencies can aggravate this pressure. They also report a connection between low transparency of automated systems and resulting time pressure. Within the *cluster (d) environmental factors/working tools*, Körner et al. [70] show a relation between technical errors and subsequent interruptions.

In sum, results of this analysis of interrelations of work factors show how strongly working conditions affect each other. If the processes within the *environmental tools/working tools* do not work, they can block each other and thus delay the entire work process. In order to be able to handle this, certain qualifications are required.

Cluster (a) cognitive demands / work content (−task) with further work factors Two studies have investigated relations within *cluster (a)* [30, 70]. Corbett [30] shows a positive significant correlation between job complexity and role breadth. Körner et al. [70] report that situation awareness and qualification were rarely linked by employees.

Corbett [30] was the only study to investigate the relationship between *cluster (a)* and *(b) social factors*. He found no significant associations between supervisor influence and role breadth, or between supervisor influence and job complexity.

For the association between *cluster (a)* and *cluster (c) organizational factors*, Brenner et al. [17] show a significant positive correlation between workload and qualification. Körner et al. [70] report positive effects of human-machine interaction on flexibility in the work process.

In sum, the studies of this cluster combination show that the complexity to be managed as well as the qualification of employees are essentially related to the successful management of workload.

Figures 5 summarizes the associations between the work factor clusters and activity groups.

Activity group 1 (ag1) - extent of technology use Four studies from *(ag1)* examined work factors from *cluster (a) cognitive demands/work content (−task).* Andries et al. [4] showed variations in task variability, autonomy, and qualification for different activity groups in the automation sector. Claussner and Müller [29] considered task variability, degrees of freedom, responsibility, cognitive and physical demands of workers at conventional and flexible automated die-casting machines. Overall, he found that work at the automated machine is more beneficial in terms of personality development as it offers for example a greater task variability and more latitudes, more responsibility, and fewer physical demands. Rutenfranz et al. [109] show different degrees of complexity depending on the automated task area. The highest degree of complexity was found for those with the highest requirements in handling automated work orders. In Stellman et al. [114], the group which used digital tools to the greatest extent (all-day VDT user) had the lowest decision latitude, transparency, variability, and learning requirements.

Summarizing the results, it seems as if the *extent of technology use* is unanimously seen as a factor changing the cognitive demands of work – sometimes resulting in higher cognitive demands with higher qualification demands but sometimes also in lower cognitive demands, which means a dequalification of employees.

Associations of *(ag1)* with *cluster (c) organizational factors* predominantly contained time pressure and workload. Dainoff et al. [32] report that the VDT-time (as group defining feature) had a significant negative correlation with job pressure. Employees who spent the least time working before the screen reported the highest job pressure. In contrast, Stellman et al. [114] report the highest workload for all-day VDT users. Rutenfranz et al. [109] show that the different degrees of activity can

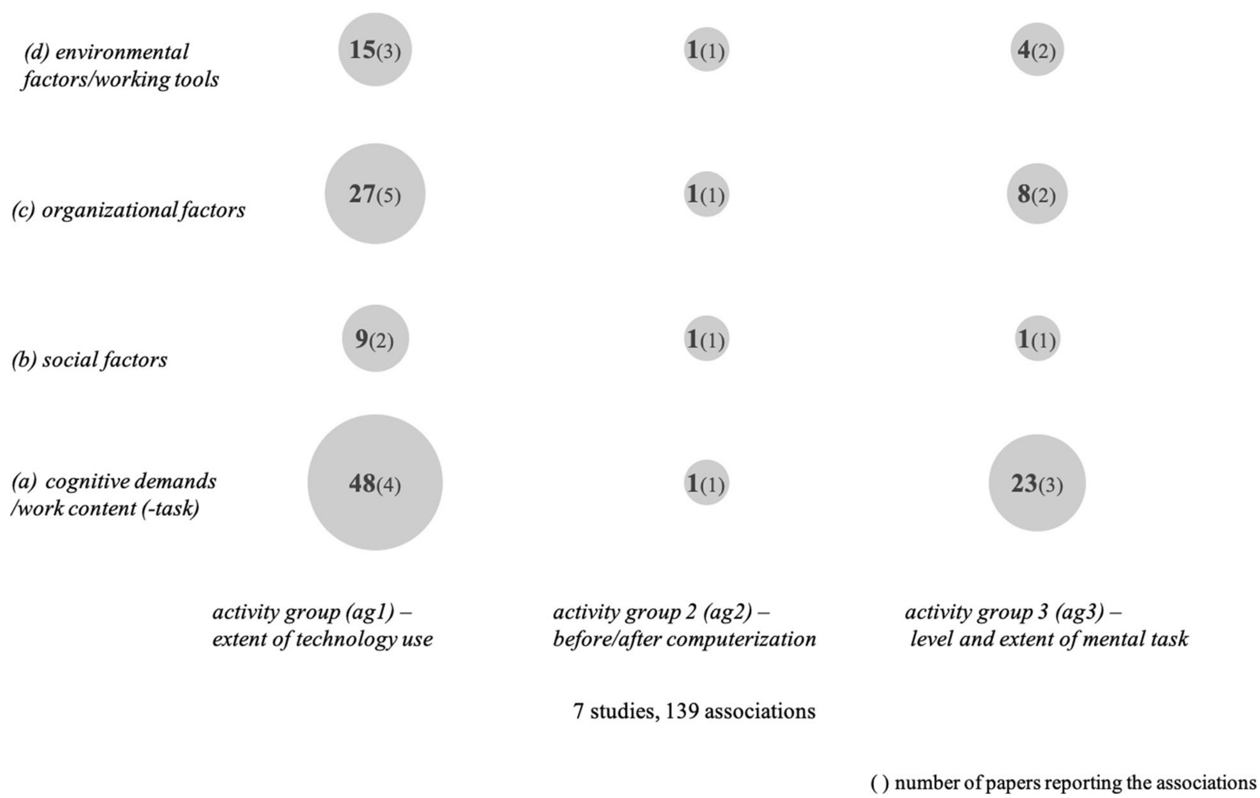

Fig. 5 Frequency of associations between activity groups and work factors

be seen above all in the demands of experiencing time pressure. This results from a responsibility for errors and the resulting possible delays in the process.

The combinations of *(ag1) - extent of technology use* and *cluster (d) environmental factors/working tools* are limited to ergonomic aspects. For example, VDT-time and light have a highly positive significant correlation [32]. Stellman et al. [114] report the highest levels of ergonomic stressors for the group with the highest level of technology use.

Two studies investigated associations with *cluster (b) social factors*. The focus is on feedback [29] and on leadership and corporate culture [4], but both do not report results.

Activity group 2 (ag2) - before/after computerization Brenner et al. [17] is the only study covering *(ag2) - before/after computerization*. They considered one connection to every cluster of work factors. Related to *cluster (a) cognitive demands/work content (−task),* work after computerization is perceived as more qualified than before automation. Concerning *cluster (c) organizational factors,* technology-induced interruptions result in higher workload. Handling these interruptions requires more attention by the employees.

Activity group 3 (ag3) - level and extent of mental task Three of the four studies in *(ag3) - level and extent of mental task* examined associations with work factors [58, 65, 111]. They observed that tasks with higher mental demands are – to varying degrees – accompanied by higher control (time- and content-related), various and more challenging subtasks, better planning possibilities, and more qualification requirements. Workload, recorded as quantitative overload and time pressure in this study, increased with more automated and restrictive tasks, similar to the reports from *(ag1)- extent of technology use.*

In sum, associations from *(ag3)* highlight that an increased use of technologies seems to increase the occurrence of workload and time pressure.

Discussion

The aim of this systematic review was to assess working conditions related to digitally connected work and to provide an overview of associations with various health and well-being outcomes. We identified and analyzed 14 studies from 1981 to 2019, five of them from the GDR [29, 58, 65, 109, 111]. A total of 5235 employees from the production and service sectors were examined. Despite of our focus on digital technologies in the search string, most included studies were conducted before

2000. The large time span of the studies, which thematically covers the introduction of automation and computerization to extensive digitization, is reflected in a heterogeneous study situation. The majority of the studies rely on "classical" working conditions (e.g., decision latitude, task variability) and established concepts and theories (e.g., Job-Demand-Control), regardless of the degree of digitization.

A major focus of all studies is on the work factor cluster *cognitive demands*. Especially its numerous combinations with the cluster *environmental factors/working tools* as well as the frequent connections to the cluster *organizational factors* are an indication of the growing complexity of work and working conditions with digitization mentioned in the introduction. *Social factors* on the other hand have hardly been researched. The identified relations to and effects on health and well-being resulting from these working conditions are diverse.

With regard to health outcomes, differences in the focus of old and new studies are striking. While older studies have a strong emphasis on strain-symptoms such as *physiological parameters and somatic complaints*, these do not play a role in the newer publications. The focus of the newer papers is clearly on psychological states like motivation and satisfaction as well as subjective evaluations (of affective symptoms). *Reduced well-being/affective symptoms* are researched in older and newer studies alike.

This difference might not primarily be attributable to digitization but rather to a general trend toward individualization within Western societies that is also reflected in the world of work. It puts the individual with their needs at the center of attention. The desire for appreciation of one's own work performance or the demand for more individual flexibility are indicators of this subjectification of work [84]. However, in line with earlier research on the health impact of working conditions, a reversal of this trend in research can be observed: objective health outcomes gain new attention, and more and more research is being conducted in this field [74]. Modern sensor technology permits real-time monitoring of physiological parameters like heart rate and heart rate variability [93]. In addition, other rather new approaches such as immune markers are being pursued [75]. Using these developments in a multimethod approach including diverse dimensions of health could be helpful for a better understanding of relations and interactions of health and work factors in complex work systems.

Regarding work factors, the main cluster of *cognitive demands* includes important elements of a personality-promoting work design like "qualification". This work factor was considered in old and new studies leading to the conclusion that fundamental skills are needed throughout the entire digitization process [4, 17, 29, 58, 65, 70, 114]. In addition to specific knowledge on the digital tools used, cognitive skills such as literacy, numeracy, and problem-solving are necessary as superordinate competencies [56].

Furthermore, the shift in the predominance of mental over physical tasks such as monitoring and controlling highlights a widely discussed digital dilemma: The possibility of simplifying or even replacing work processes results in deskilling for some employees, but at the same time also enforces a specialization of others. The conclusion that regular training as well as continuous education and participation seem to be required to meet the changing demands is not a new one [17, 19, 70]. But it does suggest that the possibility of continuous qualification as a part of personality-promoting work design will continue to be of importance in increasingly complex systems [100, 119].

Although individual qualification and competence are important, organizational factors are decisive for the effects of digitally connected work [88]. This is also reflected in relevant organizational work factors identified in the studies, above all workload and time pressure [4, 17, 29, 32, 58, 109, 114]. Furthermore, the influence of work organization and task design on the health of employees is often rated higher than or equally high to the influence of technologies per se: for example, Dainoff et al. [32] show that pressure is not dependent on the pure time spent at the computer. Rutenfranz et al. [109] conclude that the design of breaks has a greater influence on the health of employees than the machines they work on, and Umans et al. [117] show a moderating effect of corporate culture on the relation between the design of the digital work environment and job satisfaction. Concluding, Hacker and Schönfelder [58] see the critical influence on employees' health and well-being in the organization of work and thus do not expect a "compelling relationship" between the introduction of computers and the improvement of working conditions, and Jackisch et al. [65] conclude that health consequences are generally caused by a complex set of conditions rather than isolated cause-effect relationships. Taken together, technology applications are always embedded in the design and organization of work which, in turn, should be included in analyses [70]. The complex set of conditions resulting from the embedding of technological tools seems decisive for the effects of digitally connected work [85, 88] and an isolated evaluation of tools and systems without considering the organizational context is not recommendable [23, 34].

In line with this reasoning, it seems important that work design reflects technological developments to evolve concurrently. Interestingly, older studies in this review, contrary to newer ones, examined technologies not only in terms of varying usages, but often with a deep reflection of their function [29, 32, 58, 65, 99, 109, 114]. This has been dispensed in the newer studies which is certainly due to the fact that the use of technological tools and applications is omnipresent nowadays [22, 41]. Additionally, the ergonomic aspects in work design were only approached in older texts [32, 114], probably due to emerging ergonomic standards such as DIN EN ISO 6385 [39] and the implementation of further occupational health and safety rules over time. But it is particularly striking that the work-factor cluster *environmental factors/working tools*, compared to others, has been most often considered in connection with other work factors like work organization, such as the association of interruptions due to technical reasons with increased time pressure [58, 70, 109]. Assuming that organizational structures and technology are fusing more and more with increasing connectivity/complexity of work, the reflection of technological functions and their embeddedness in work organization might be of increasing importance for the advancement of work design in digitally connected work.

One limitation of this systematic review could be the search string. It was not restricted to a particular time in order to identify possible transitions. We assumed that a search string that reflects newest digital technologies would set an automatic limit and clear focus. Nevertheless, we found a high degree of studies rooted in early days of digitally connected work. A possible explanation for this might be that we included new technologies in the search string, but also terms of human-computer interaction. Some of them might have already been used in the early days of computerization but are – with a different connotation – still relevant in digital connected work systems today. At the same time this enables an essential result of our review. We revealed many similarities concerning terms, working conditions and work design research between the first wave of automation and current digitalization. This points more to a gentler digital transition than to the often stated "disruptive technological change" [28]. A similar conclusion is drawn by Diebig et al. [36] concerning the relevance of classical working conditions in industry 4.0.

Nevertheless, the covered time span was a challenge for the assessment of the study quality and the summary of the results. The used QATSDD tool is well suited for the combination of quantitative, qualitative, and mixed-method studies, but the evaluation of older texts (especially from the GDR) was difficult with this approach. The quality of the studies cannot necessarily be judged worse by a lower overall score since many of the standards in this tool have been established only in recent years. An individual consideration of the respective results is therefore important for an overall assessment of the papers.

Based on the described heterogeneous study selection and the associated different approaches, it is not possible to carry out statistical evaluations or even a meta-analysis. A comparatively uniform approach for the evaluation and analysis of the results across studies was achieved by clustering the working conditions according to the risk assessment criteria of the European Commission [42].

In conclusion, even as the digital tools themselves have changed in the development from computerization and automation to digitization, this systematic review shows that the prevailing working conditions, such as cognitive demands, time pressure or workload, and their underlying work design theories remain relevant over time, even though their relations and importance shifted. Unfortunately, not all of the identified health outcomes and/or working conditions were analyzed in relation to each other. Our form of clustering reveals such gaps in research. Nevertheless, the associations found between the different clusters show that many factors can act as complexity drivers in a technologized work environment that might impact strain of employees in a multitude of ways. Future research should combine the context-rich approach of older studies with new methodological developments to cover this complexity and advance health- and personality-promoting work design in digitally connected work.

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Authors' contributions
SZ, BHei and BHer developed the methodological concept. SZ, BHei and BHer screened titles and abstracts of the studies and examined the full texts for inclusion. SZ and BHei performed the data abstraction from the included articles, evaluated the study quality and visualized the results. SZ drafted the manuscript. SZ, BHei and BHer participated in the interpretation of the study results and the drafting of the manuscript. All authors read and approved the final manuscript.

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ORIGINAL ARTICLE

Autonomy in the context of cognitive demands—is the resource becoming a stressor?

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Abstract

Objective Autonomy is often associated with positive linear effects on health whereas non-linear correlations have received only sporadic attention. Assuming that the use of autonomy also represents a cognitive demand, this study examines whether health effects of autonomy change depending on further cognitive demands and whether curvilinear relationships can be identified.

Methods A survey was carried out in three SMEs with established work analysis questionnaires. 197 Employees were classified into groups with high and with low cognitive demands by means of a two-step cluster analysis. This was modeled as moderator together with curvilinear effects of autonomy in regression analyses.

Results Curvilinear associations were found for emotional exhaustion, cynicism, and anxiety. They were strongest for anxiety. No moderating effects of cognitive demands and no consistently significant modeled relations were found.

Conclusion The results confirm that autonomy has a positive influence on the health of employees. However, autonomy should not be seen as an isolated resource but embedded in the organizational and societal context.

Keywords Digitalization · Autonomy · Cognitive demands

Introduction

In essence, autonomy at work, including some conceptual gradations such as degree of freedom, latitude or control, is to be understood as the degree of influence on the processes and results of one's own work (Sparks et al. 2001; Morgeson and Humphrey 2006; Sichler 2006). Influence can refer to the following three areas: first, the organization of action, second, the design of ways of working, and third, the ability to make decisions and set tasks oneself (Ulich 2011). In a similar way, Humphrey et al. (2007) describe three facets of autonomy: work scheduling autonomy as the freedom to control the scheduling and timing of work, work methods autonomy as the freedom to control which methods and procedures are utilized, and decision-making autonomy as the freedom to make decisions at work. They also propose differences in the magnitude of relations of the facets to work outcomes. Although this differentiation in facets has already existed for a long time (Jackson et al. 1993; Karasek et al. 1998), autonomy or job control is often equated only with the last area of influence, that is, decision-making autonomy.

Autonomy in general is understood as a resource in theories of work psychology, such as the Job Characteristics Model (Hackman and Oldham 1976), the Job Demand Control Model (Karasek 1979; Karasek and Theorell 1990), or in its extension to the Job Demands Resources Model (Bakker and Demerouti 2007). Autonomy is thus not only one of the central components of work design that promotes learning, personality and health, but can furthermore be classified as a fundamental human need. That is, an increase in autonomy has a potentially health- and personality-promoting effect, while a low level of autonomy conversely has negative effects (for review, Bonde 2008; Stansfeld and Candy 2006; Spector 1986; Häusser et al. 2010; de Lange 2003; van der Doef and Maes 1999, Rau and Buyken 2015; Nixon et al. 2011; Theorell et al. 2015, Theorell et al. 2016). This effect has been found for numerous health, well-being, and performance parameters, such as job performance and work engagement (Schaufeli et al. 2009; Nagami et al. 2010), well-being and job satisfaction (Cheung et al. 2015),

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emotional exhaustion (Van Ruysseveldt et al. 2011), depression (Ahlin et al. 2018; Madsen et al. 2017), mental health (Bentley et al. 2015; Butterworth et al. 2011), psychiatric status (Stansfeld et al. 1999), and even somatic conditions such as high blood pressure (Steptoe and Willemsen 2004). In the modern highly connected world of work, demands, stressors and resources have changed significantly (Allvin et al. 2011; Höge 2011). In many cases, the new forms of work are associated with higher cognitive demands and increased task complexity in addition to work intensification (Burchell et al. 2002; Cascio and Montealegre 2016; Burke and Cooper 2002; Meyer and Hünefeld 2018; Schaufeli and Taris 2014).

At the same time, the degree of autonomy in work has increased for many employees, especially in the course of flexibilization (Wood 2011; Pongratz and Voß, 2003). Often, this is linked to new management methods that place a strong responsibility for task and goal fulfillment on individual employees (Moldaschl and Voß, 2002; Sichler 2006; Höge 2011; Bredehöft et al. 2015). Opportunities thus become necessities, requiring increased responsibility as well as higher performance (Shazad 2021; Nagel 2010). These factors, as well as new forms of management, some of which are manifested in higher participation opportunities for employees, can thereby provide for an increase in psychological stress (Busck et al. 2010). Under these conditions, autonomy can change from a resource to a stressor because an increase in autonomy in the new world of work is linked to demands for additional (self-)organization and planning, which ties up "psychological capital" such as self-efficacy or resilience (Shazad 2021; O'Donnell et al. 2015).

Similar considerations can be found in theoretical approaches, such as the vitamin model (Warr 1990), the assumption of a "too-much-of-a-good-thing" (TMGT) effect (Grant and Schwartz 2011; Pierce and Aguinis 2013), or a "choice overload" (Schwartz 2004), which assumes that too many fundamentally beneficial working conditions, such as autonomy, will eventually cause the positive effects to stagnate or even turn into negative effects.

The assumption of an inverted U-shaped or otherwise nonlinear effect of autonomy, job control or decision authority has been investigated by a number of studies in recent years. The health outcomes collected in these studies are as diverse as the occupational groups and topics of focus. Chung-Yan (2010) found a stagnation of the positive effect of autonomy on well-being and job satisfaction for employees with high job complexity, while employees with lower complexity continued to benefit positively linearly from autonomy. In contrast, De Jonge and Schaufeli (1998) found the highest values for emotional exhaustion at an intermediate level of autonomy and thus an inverted U-shaped relationship. Nonlinear correlations of autonomy with job satisfaction or well-being and emotional exhaustion were found in both Rydstedt et al. (2006) and Kubicek et al. (2014). Stiglbauer and Kovacs (2018) partially demonstrated that autonomy shows inverted U-shaped trajectories with well-being but that it is strongly dependent on the operationalization and the respective facet of autonomy. Flynn and James (2009) showed in their experimental study that cardiovascular reactivity was similar for high and low control. In addition to nonlinear trajectories, there are also results on negative linear relationships: Joensuu et al. (2010, 2012) showed that high rather than low decision latitude increased the risk of depression and cardiovascular and alcohol-induced disease. Signs of a higher risk of cardiovascular disease were also found by McCarthy et al. (2014) to be present in older workers with high job control. In an experimental design, O'Donnell et al. (2015) found that although no negative effects of autonomy were reported in the surveys, the physiological parameters collected showed that increased autonomy can induce stress responses. However, the results of these studies differ considerably, and there are some studies that could not find significant results despite the investigation/assumption of a negative linear or curvilinear relationship. Jeurissen and Nyklíček (2001) were also unable to confirm curvilinear relationships.

These ambiguous, inconsistent results suggest that other factors and constellations of demands might be responsible for the varying types of relationships between autonomy and health outcomes, and that further individual and contextual factors, potentially moderators (Stiglbauer 2017) and organizational demands (Clausen et al. 2022) should be taken into account, as is already evidenced in the Job Demand Control model where the combination of high job demands and low job control are usually associated with negative health effects (de Lange et al. 2002; van der Doef and Maes 1999). Thus, in addition to the degree of autonomy, the efficacy of positive effects also seems to depend on whether the resource autonomy can come into play in the concrete work condition structure (Stiglbauer 2017).

Against this background, we argue in the remainder of this paper that task-related requirements on cognition might pose one especially important moderator for the relationship between autonomy and health of employees in those working conditions that have changed as a result of developments in digitization, that is, increased work intensity and complexity, increased quantitative demands, and the cognitive demands on employees (Meyer and Hünefeld 2018; Zolg et al. 2021). The reasoning behind this assumption is that the use of autonomy and especially decision-making autonomy requires cognitive performance, like e.g. planning and complex problem-solving. If this requirement acts "on top" of already high task-related cognitive demands, it might be overtaxing and, therefore eliminate the positive effect on employees' health. That is, we propose an interaction of autonomy and task-related cognitive demands. Dettmers and Bredehoeft (2020) use a similar reasoning in their study; however, instead of existing work design concepts they propose a new concept called "job design demands" as mediator between autonomy and emotional exhaustion and irritation, respectively, that can explain potential negative effects and is labeled the "dark side" of autonomy by the authors. In contrast, our approach is parsimonious and tries to retain the positive concept of autonomy including its requirements as an inherently health- and personality-promoting work characteristic (Hackman and Oldham 1976; Humphrey et al. 2007). Effects of different facets of autonomy could then be hypothesized as depending on the cognitive performance each facet requires and adds to other task-related cognitive demands. For example, decision-making autonomy as a complex problem-solving task might tie up more cognitive resources than activity latitude.

The aim of this paper is therefore to determine whether the influence of autonomy on various health factors depends on the level of task-related cognitive demands. We assume that autonomy should basically be evaluated as a resource, which, however, can develop into a stressor under the condition that task-related cognitive demands are already high and trying. Task-related demands are operationalized by a clustering of a number of different demands usually surveyed in work design questionnaires (see "Methods and Materials" section). We look at these proposed associations for a range of health outcomes to determine whether general patterns can be identified. We also expect different results for the three facets of autonomy. For example, as decision latitude is probably the facet with the highest cognitive requirements, we expect that we will see a moderation with task-related cognitive demands in the sense of curvilinear effects for participants with high task-related demands, whereas this might not be the case for activity or design latitudes.

The following hypotheses and research questions are examined:

1. Is there a positive effect of autonomy that can be confirmed consistently for all health parameters surveyed? (Hypothesis 1: positive linear association).
2. Is this positive effect of autonomy moderated by the level of task-related cognitive demands an employee has? (Hypothesis 2a: moderated association).
3. Are high task-related cognitive demands likely to cause the positive effect to stagnate or reverse at some point? (Hypothesis 2b: direction of moderation: low/middle cognitive demands = positive linear association; high cognitive demands = curvilinear/nonlinear association).
4. Do these effects differ for the three facets of autonomy (activity-, design-, and decision-latitude)?

Methods and materials

Design

We used a cross-sectional design to survey the latitudes at work, task-related cognitive demands and health outcomes of employees. The study is part of the LedivA project (Leistungsregulierung bei digital vernetzter Arbeit-Performance regulation in qualified digitally connected work) that investigates the working conditions and the physical and mental strain resulting from digitally connected work. All data were gathered between September 2019 and December 2019. The study was approved by the Ethics Committee at the Faculty of Medicine, Ludwigs-Maximilians-University, Munich (ID: 19–430).

Participants

Employees of three small and medium-sized enterprises (SME) were recruited. Two of the SMEs were from the manufacturing sector and one was from the service sector. As employees at industrial workplaces would otherwise not be reached, the survey was conducted as a paper-and-pencil questionnaire and fill-in time was working time for all participants. Due to data protection measures, employees could not be directly approached but via contact persons in the enterprises who were informed in advance about the objectives and procedures of the project. Employees received this information via internal communications and in the informed consent forms that were sent together with the questionnaires as packages to the contact persons in all companies who distributed these to all employees at a fixed start date. A four-week deadline for submitting the questionnaires were communicated to everyone. Those who wanted to participate in the survey had to return the signed consent forms in separate envelopes. The questionnaires could be returned in sealed envelopes put in locked boxes (both provided by the project) in easily accessible rooms in the enterprises. As no direct contact with the employees was possible, contact persons received up to two reminders by email and telephone to be relayed to all employees. Of the 433 employees invited to take part in the survey, 197 (45.5%) completed and returned the questionnaire. The response rate in the companies was 31.8%, 42.6% and 100%, respectively. Although on the low side, this response rate falls within the range of average rates and continuing decline in response reported in literature for organizational research (Anseel et al. 2010; Baruch and Holtom 2008; Weigold et al. 2019). The range of response rates results from the respective organizational structures (e.g., number of sales representatives difficult to reach, availability of in-house mail, size of enterprise with the smallest enterprise showing full participation), and situations (e.g., holidays, volume of work in the respective survey timeframe with one enterprise having a strong seasonal business) as well as the different approaches to the survey of the responsible contacts and their motivating power.

Measures

Descriptive values, internal consistencies and intercorrelations for all scales are presented in Table 1. Sample items from German questionnaires are in most parts ad hoc translations.

a) Dimensions of autonomy

Autonomy was assessed with the German self-report instrument "Activity and Work Analysis" (TAA) by Glaser et al. (2020) containing three subscales: *activity latitude* (e.g., I can decide for myself which working methods and tools to use, 3 items), *design latitude* (e.g., My work permits using my own ideas, 3 items), and *decision latitude* (e.g., I can make my own decisions about work goals, 3 items). All three subscales use a 5-point Likert-scale (1 = no, not at all, 5 = yes, exactly). *Overall task latitude* (autonomy) contains all nine items.

b) Task-related cognitive demands

Mental demands were assessed with four items from the TAA (Glaser et al. 2020) (e.g., My work requires weighing various aspects to complete my tasks (1 = no, not at all, 5 = yes, exactly)). *Knowledge demands* were measured with a single item (Does your work require broad knowledge?) from the Copenhagen Psychosocial Questionnaire (COPSOQ, Kristensen et al. 2005; German version Nübling et al. 2005) with a 5-point Likert scale from 1 = to a very small extent to 5 = to a very large extent.

Further cognitive demands were assessed with the German version (Stegmann et al. 2019) of the Work Design Questionnaire (WDQ, Morgeson and Humphrey 2006). With four items each and 5-point Likert-type scales, these include *skill variety* (e.g., The job requires a variety of skills (1 = strongly disagree, 5 = strongly agree), *complexity* (e.g., The job requires that I only do one task or activity at a time (1 = strongly disagree; 5 = strongly agree; recoded), *problem-solving* (e.g., The job often involves dealing with problems that I have not met before), and *information processing* (e.g., The job requires me to monitor a great deal of information).

c) Health outcomes

To cover a range of possible health outcomes, we collected short- and long-term general and work-related variables. We assessed *anxiety* in a nonclinical context (e.g., I avoid addressing my supervisor at work; 7 items) with a 7-point Likert-type scale (1 = strongly disagree; 7 = strongly agree) from Mohr and Müller (2014).

The German version of the Maslach Burnout Inventory (Maslach and Jackson 1981; Büssing and Perrar 1992) was used to assess the two key burnout components *emotional exhaustion* (e.g., At the end of a workday, I feel used up, 3 items) and *cynicism* (e.g., I have become more cynical about whether I am making any contribution with my work, 3 items) with a 6-point frequency scale (1 = never; 6 = very often).

Well-being/depression was assessed with the WHO Five Well-Being Index (World Health Organization (WHO) 1998) with five items (e.g., Over the last two weeks, I wake up feeling fresh and rested) using a 6-point scale (0 = at no time; 5 = all of the time).

To assess *cognitive irritation* (e.g., I have difficulty relaxing after work), we used a 7-point Likert-type scale (1 = strongly disagree; 7 = strongly agree) (Mohr et al. 2005).

To assess work ability, we used an abbreviated German version of the WAI Workability Index developed by Tuomi et al. (1998) (Müller et al. 2016). The items (work ability in relation to physical and mental demands of work) used a 5-point Likert scale (1 = very poor; 5 = very good) and an overall ability rating with an 11-point scale (0 = cannot work at all; 10 = currently the best work ability).

d) Control variables

Information on control variables *age* and *gender* are based on self-reported data from the questionnaire. Participants were also required to match themselves to a *job description* appropriate for their position. They could choose between four different types of jobs: semiskilled/assisting work, qualified work, work with specialist responsibility, or work with extensive management responsibilities and decision-making powers.

Statistical analyses

We conducted descriptive analyses for each of the outcome and latitude variables by using means and standard deviations (SDs), frequencies, and percentages. Furthermore, to capture the relationships of the variables, we performed correlation analyses.

To identify the employees with different levels of cognitive demands, we used a two-step cluster analysis (e.g., Benassi et al 2020) with the six measured task-related cognitive

Table 1 Means, standard deviations, Cronbach's alpha reliability coefficients, and intercorrelations between all variables

	Variables	M ± SD	Scale range (items)	1	2	3	4	5	6	7	8	9	10	11	12	13
1	Age	41,92 ± 12,59														
2	Gender		0 = *m*;1 = *f*	− 0.08												
3	Job description	1.97 ± 0.86	1–4[a]	0.08	− 0.31***											
4	Subscale activity latitude	3.86 ± 0.87	1–5[a] (3)	− 0.04	0.05	0.11	(0.78)									
5	Subscale decision latitude	2.87 ± 0.91	1–5[a] (3)	0.07	− 0.21***	0.38***	0.54***	(0.78)								
6	Subscale Design Latitude	3.17 ± 1.08	1–5[a] (3)	0.08	− 0.25***	0.29***	0.53***	0.58***	(0.89)							
7	Overall autonomy	3.30 ± 0.80	1–5[a] (9)	0.05	− 0.18*	0.31***	0.80***	0.84***	0.86***	(0.89)						
8	Emotional exhaustion	3.30 ± 1.20	1–6[a] (3)	0.06	0.02	0.08	− 0.12	− 0.19***	− 0.14*	− 0.19*	(0.92)					
9	Cynicism	2.78 ± 1.20	1–6[a] (3)	− 0.09	− 0.04	0.04	− 0.17*	− 0.18*	− 0.14*	− 0.19***	0.56***	(0.88)				
10	Anxiety	2.40 ± 1.18	1–7[a] (7)	− 0.04	0.28***	− 0.15*	− 0.20***	− 0.33***	− 0.27***	− 0.32***	0.49***	0.43***	(0.83)			
11	Cognitive irritation	3.61 ± 1.60	1–7[a] (5)	0.16*	− 0.12	0.24***	− 0.11	0.02	0.00	− 0.04	0.58***	0.33***	0.37***	(0.88)		
12	Workability index	4.03 ± 0.67	1–5[a] (3)	− 0.03	− 0.04	0.13	0.26***	0.23***	− 0.27***	0.30***	− 0.50***	− 0.47***	− 0.41***	− 0.34***		
13	Well-being	2.84 ± 1.16	1–5[a] (5)	0.13	− 0.10	0.11	0.15*	0.23***	0.29***	0.28***	− 0.43***	− 0.42***	− 0.49***	− 0.32***	.51***	(0.90)
14	Cognitive demands cluster		0 = middle/low; 1 = high	0.03	− 0.31***	0.43***	0.26***	0.35***	0.37***	0.39***	0.11	− 0.00	− 0.17*	0.21***	0.08	0.16*

Correlation coefficients according to Spearman (Cognitive Demands/Job Description), Kendall (Job Description—Gender) and Pearson (all other variables), reliability according to Cronbach's Alpha (in parentheses), **p* value ≤ .05, ***p* value ≤ .01, ****p* value ≤ .001.

[a]Higher values = higher expression

demands. The log-likelihood method was used for distance measures. The number of clusters was not prespecified. As an overall goodness-of-fit measure of the cluster structure the silhouette measure of cohesion and separation (Kaufman and Rousseeuw 1990; Rousseeuw 1987) was used. The silhouette value essentially captures how similar an object is to its own cluster (cohesion) compared to other clusters (separation); the coefficient is basically the difference between cluster separation and cohesion divided by the maximum of the two (Rousseeuw 1987). It ranges from − 1 to 1. A score above 0 ensures that the within-cluster distance and the between-cluster distance is valid; scores above 0.2 are usually evaluated as fair, at or above 0.5 as good (Tkaczynski 2017). To determine the best cluster solution, that is, the most parsimonious cluster solution with the best fit, we adopted the procedure used by Benassi et al. (2020) with evaluations for up to four clusters as a reasonable number for classification. Akaikes Information Criterion (AIC) and Bayesian Information Criterion (BIC) changes were calculated as the difference between two cluster solutions starting from the most parsimonious (one cluster) to the least parsimonious (four clusters). With this procedure, a two-cluster solution proofed to be the best solution. From this, we derived the binary variable *cognitive demands* (CD) ("low/medium cognitive demands" = 0, "high cognitive demands" = 1). For the results of the cluster analysis, see "Results of regression analyses".

In preparation for the subsequent analyses, we identified unusual cases by specifically looking for deviations and anomalies from the normal values of the groups. Two cases from the cluster with higher cognitive demands were then excluded from the analysis. To assess whether cognitive demands have a moderating curvilinear effect on the relationship between autonomy and various health outcomes, we then conducted hierarchical moderated regression analyses.

In step one, we controlled for age. To avoid multicollinearity problems, we decided against using gender as a control variable because chi-square tests confirmed that gender is already represented in the clusters; that is, in the cluster of high cognitive demands, 70.1% of participants are male (see section "Cluster analysis"). We also decided against including the variable job description as a control variable for similar reasons. As seen in the results in the correlation table, correlations are clearly visible between this variable and the variables age and gender.

In a second step, we added the variables on autonomy (A), the cluster variable (CD) and the interaction term to test the main effects and the linear moderation.

In steps three and four, quadratic and cubic terms for autonomy and their respective interaction with the cognitive demands were added to test for curvilinear moderation effects.

All analyses were conducted with IBM SPSS Statistics 26.

Results

Study population

A total of 193 employees (37.1% women, 60.9% men) with an average age of 41.9 years (19–70, SD = 12.6) were included in the analysis. A secondary school diploma or lower was held by 34.4%, an intermediate school-leaving certificate by 36% and an applied or general university entrance qualification by 28.9%. Based on data from the companies, 83.2% of the participants worked in the production sector and 16.8% worked in the service sector. Job descriptions of the employees covered semiskilled/assisting work (20.0%) and qualified work (55.6%) as well as independent work with specialist responsibility (20.6%) and work with extensive management responsibilities and decision-making powers (3.9%). Duration of employment at the respective company was rather high: Only 6.8% of participants worked for less than one year at their job, whereas 27.4% worked more than five years and 33.7% more than ten years at their current job.

Cluster analysis

The two-step cluster analysis of the six task-related cognitive demands resulted in a two-cluster solution. Changes in AIC and BIC confirmed this solution as the best, most parsimonious model (Δ AIC: 2 vs. 1 cluster = − 206.33, 3 vs. 2 = − 65.90, 4 vs. 3 = − 19,19; Δ BIC: 2 vs. 1 cluster = − 167.18, 3 vs. 2 = − 26.74, 4 vs. 3 = 19.96). The two cluster outcome showed a fair silhouette measure of cohesion and separation of 0.50 indicating a medium-sized structuring, while with fixed cluster numbers the silhouette measures were considerably lower (3 and 4 clusters 0.30). Therefore, the two-cluster solution was used in all further analyses. The two groups could be defined as one group with high cognitive demands ($n = 134$) and one group with low/medium cognitive demands ($n = 59$). The means of the six included variables dividing the cluster differed by an average of 1.15 points on the 5-point scales; the predictor importance for each variable for the clustering shows a rather high relative importance of all variables with mental demands being the most and knowledge demands being the least discriminative between groups (see Table 2 and Fig. 1).

The (clusters of) cognitive demands also differ in their composition regarding age, gender, and job description. More than half of all women are found in the group with lower cognitive demands, while more than two-thirds of all men are found in the cluster with high cognitive demands. In both clusters, approximately half of the employees perform

Table 2 Characteristics of the Cluster "cognitive demands"

Cluster "cognitive demands"	Mental demands M ± SD	Skill variety M ± SD	Complexity M ± SD	Information processing M ± SD	Problem-solving M ± SD	Knowledge demands M ± SD
Low/medium	2.71 ± 0.62	2.84 ± 0.61	3.13 ± 0.76	3.17 ± 0.67	2.21 ± 0.72	3.03 ± 0.83
High	4.15 ± 0.61	4.07 ± 0.60	4.06 ± 0.61	4.15 ± 0.57	3.54 ± 0.73	4.05 ± 0.69
Predictor importance	1.0	0.83	0.47	0.59	0.70	0.46

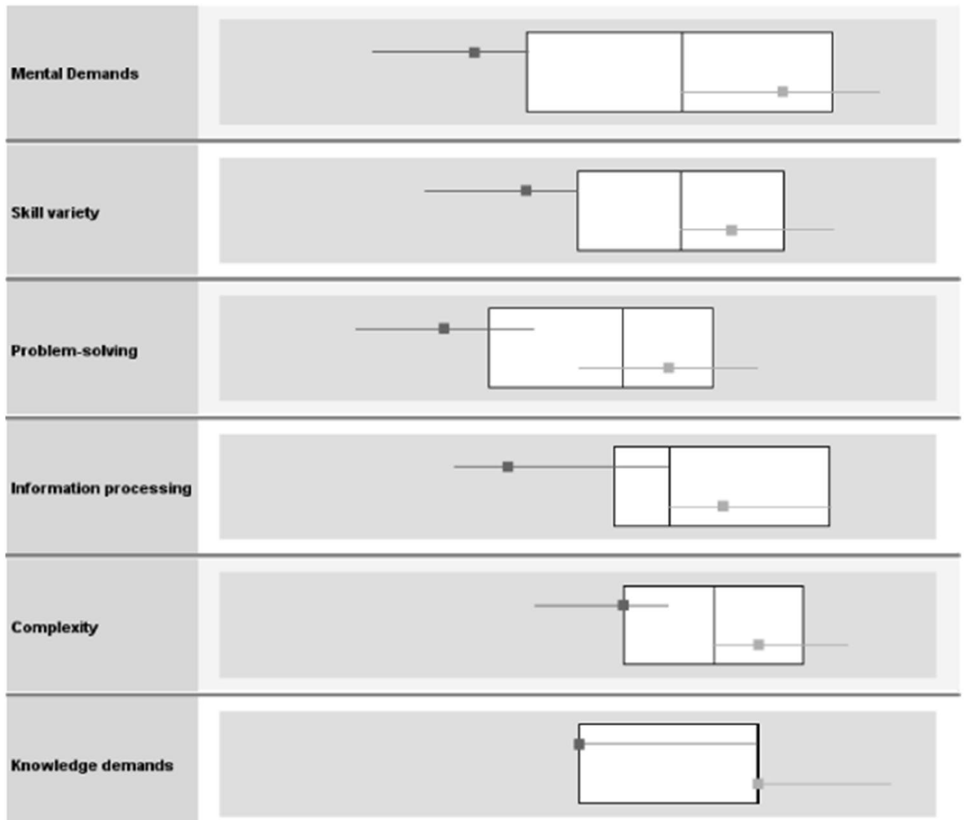

Fig. 1 Boxplots of value distributions in the general sample (median, 25th and 75th quantile), the low/medium cognitive demands group (upper dark grey line) and the high cognitive demands group (lower light grey line)

qualified work. Work with extensive management responsibilities and decision-making powers is not present in the cluster with lower cognitive demands (see Table 3). With regard to the age distribution, the significant difference between the clusters can be attributed exclusively to the high proportion of trainees in the cluster with lower cognitive demands.

Descriptive analyses

Descriptive statistics and intercorrelations of all variables are presented in Table 1. In general, mean values for autonomy and its facets are at a medium (decision and design latitude, overall autonomy) to higher level (activity latitude).

The intercorrelations within the working conditions show that higher demands are also associated with higher latitudes. The intercorrelations within the health outcomes show the expected correlations; for example, higher exhaustion is associated with lower workability and lower well-being.

Correlations between working conditions and health outcomes show that autonomy, with the exception of cognitive irritation, has the expected associations with positive and negative health aspects, e.g. higher autonomy is associated with lower anxiety and higher workability.

Table 3 Cognitive demands cluster and sample descriptives

	"High cognitive demands" ($n=132$)	"Low/medium cognitive demands" ($n=59$)	Chi-square test
Sex			
Male	93 (70.5%)	22 (37.3%)	$p<.001$
Female	37 (28.0%)	35 (59.3%)	
Missing	2 (1.5%)	2 (3.4%)	
Job description			
Semiskilled/assisting	14 (10.6%)	23 (39.0%)	$p<.001$
Qualified work	73 (55.3%)	29 (49.2%)	
Work with specialist responsibility	35 (26.5%)	2 (3.4%)	
Work with extensive management responsibilities and decision-making powers	7 (5.3%)	0 (0.0%)	
Missing	3 (2,8%)	5 (8.5%)	
Age			
<25	10 (7.6%)	10 (17.0%)	$p<.001$
26–45	61 (46.2%)	22 (37.3%)	
46–70	60 (45.5%)	25 (42.4%)	
Missing	1 (0.8%)	2 (3.4%)	

Results of regression analyses

A total of six moderated hierarchical multiple regressions were conducted to test for nonlinear relationships of autonomy and high cognitive demands on emotional exhaustion, cynicism, cognitive irritation, anxiety, well-being, and workability. The results of the hierarchical moderated regression analysis of autonomy are presented in the Tables 4, 5, 6, 7, 8, 9. The results of the regression analyses with the autonomy facets activity, design and decision latitude can be found in the appendix.

Overall, the models explain only a little of the variance in the sample. No consistently significant effects are found for the health variables. Anxiety is the health outcome that is most strongly associated with the modeled relations. For none of the health outcomes moderating effects of cognitive demands were found. The results in more detail:

Autonomy and health outcomes

In the first step, the control variable age was tested. It is only for cognitive irritation and thus the first model significant (($\beta=0.174$, $p<0.05$; F (1,186 = 5.840, $p<0.05$). The older the employees are, the higher the reported cognitive irritation (see Table 7).

The linear effects of autonomy and cognitive demands as well as the linear interaction term were included in the second step. This second model is significant for all surveyed health parameters: emotional exhaustion (F (3,183) = 3.685, $p<0.01$) (see Table 4), cynicism (F (3,182) = 2.425, $p<0.05$) (see Table 5), and anxiety (F (3,182) = 5. 773, $p<0.001$) (see Table 6), cognitive irritation (F (3,183) = 4.243, $p<0.01$) (see Table 7), workability (F (3,183) = 4.705, $p<0.001$) (see Table 8), and well-being (F (3,182) = 4.508, $p<0.01$) (see Table 9). Cognitive demands as well as the interaction between cognitive demands and autonomy have no significant effect on any of the examined health variables. Linear associations of autonomy are found for cynicism ($\beta=-0.252$, $p<0.05$); that is, with increasing autonomy, cynicism decreases. Workability ($\beta=-0.333$, $p<0.01$) and well-being ($\beta=0.291$, $p<0.05$) are higher with higher autonomy.

Squared terms were included in the third step. The model was significant for cognitive irritation (F (2,181) = 4.423, $p<0.001$), but no single variables were identified to account for the effect (see Table 7).

In the last step, the cubic terms were included. The fourth models were significant for emotional exhaustion (F (1,180) = 3.528, $p<0.001$) (see Table 4), cynicism (F (1,179) = 3.331, $p<0.01$) (see Table 5) and anxiety (F (1,179) = 4.402, $p<0.001$) (see Table 6). The cubic autonomy term shows significant regression weights for emotional exhaustion ($\beta=-8.521$, $p<0.05$), cynicism ($\beta=-10.932$, $p<0.01$), and anxiety ($\beta=-6.942$, $p<0.05$).

Table 4 Hierarchical moderated regression analyses predicting emotional exhaustion

	Step 1 (control variables)			Step 2 (linear effects)			Step 3 (quadratic effects)			Step 4 (cubic effects)		
	B	SE	*β*	*B*	SE	*β*	*B*	SE	*β*	*B*	SE	*β*
Control variable (step 1)												
Age	0.006	0.007	0.064	0.006	0.007	0.068	0.007	0.007	0.070	0.006	0.007	0.067
Main effects and linear two-way interaction (step 2)												
Autonomy				− 0.342	0.183	− 0.229 +	− 1.905	1.140	− 1.274 +	− 11.226	3.865	− 7.507**
Cognitive demands				0.859	0.768	0.333	1.038	2.815	0.402	7.429	3.758	2.881*
Autonomy * cognitive demands				− 0.113	0.238	− 0.164	0.117	1.729	0.170	− 3.756	2.294	− 5.450
Quadratic two-way interaction (step 3)												
$Autonomy^2$							0.264	0.190	1.169	3.539	1.313	15.703**
$Autonomy^2$ * cognitive demands							− 0.078	0.262	− 0.472	0.484	0.341	2.939
Cubic two-way interaction (step 4)												
$Autonomy^3$										− 0.361	0.143	− 8.521*
$Autonomy^3$ * cognitive demands												
R^2			0.004			0.075			0.090			0.121
ΔR			0.004			0.071**			0.015			0.031*
F (*df*)			0.753 (1,186)			3.685** (3,183)			2.969** (2,181)			3.528*** (1,180)

+ *p*-Wert ≤ .10 **p*-Wert ≤ .05, ***p*-Wert ≤ .01, ***p-Wert ≤ .001 Cognitive Demands = Cluster of participants with high (1) and lower/medium (0) cognitive demands

Table 5 Hierarchical moderated regression analyses predicting cynicism

	Step 1 (control variables)			Step 2 (linear effects)			Step 3 (quadratic effects)			Step 4 (cubic effects)		
	B	SE	*β*	B	SE	*β*	B	SE	*β*	B	SE	*β*
Control variable (step 1)												
Age	− 0.008	0.007	− 0.083	− 0.007	0.007	− 0.077	− 0.007	0.007	− 0.078	− 0.008	0.007	− 0.081
Main effects and linear two-way interaction (step 2)												
Autonomy				− 0.381	0.188	− 0.252*	− 2.239	1.179	− 1.480 +	− 14.357	3.938	− 9.490***
Cognitive Demands				0.027	0.788	0.010	− 2.024	2.896	− 0.772	6.524	3.820	2.385
Autonomy * Cognitive Demands				0.061	0.244	0.087	1.645	1.781	2.349	− 3.368	2.333	− 4.809
Quadratic two-way interaction (step 3)												
Autonomy^2							0.313	0.196	1.373	4.569	1.336	20.033***
Autonomy^2 * Cognitive Demands							− 0.275	0.270	− 1.645	0.452	0.347	2.702
Cubic two-way interaction (step 4)												
Autonomy^3										− 0.468	0.146	− 10.932**
Autonomy^3 * cognitive demands												
R^2			0.007			0.051			0.064			0.115
ΔR			0.007			0.044*			0.013			0.051**
F (*df*)			1.287 (1,185)			2.425* (3,182)			2.054 + (2,180)			3.331** (1,179)

+ *p*-Wert ≤ .10 **p*-Wert ≤ .05, ***p*-Wert ≤ .01, ****p*-Wert ≤ .001. Cognitive Demands = Cluster of participants with high (1) and lower/medium (0) cognitive demands

Table 6 Hierarchical moderated regression analyses predicting anxiety

	Step 1 (control variables)			Step 2 (linear effects)			Step 3 (quadratic effects)			Step 4 (cubic effects)		
	B	SE	*β*	*B*	SE	*β*	*B*	SE	*β*	*B*	SE	*β*
Control variable (step 1)												
Age	− 0.005	0.007	− 0.055	− 0.003	0.006	− 0.035	− 0.003	0.006	− 0.032	− 0.003	0.006	− 0.034
Main effects and linear two-way interaction (step 2)												
Autonomy				− 0.265	0.171	− 0.186	0.423	1.063	0.298	− 6.787	3.625	− 4.781 +
Cognitive demands				0.616	0.716	0.251	4.774	2.627	1.958 +	9.724	3.528	3.967**
Autonomy * cognitive demands				− 0.248	0.222	− 0.379	− 2.799	1.614	− 4.274 +	− 5.799	2.154	− 8.856**
Quadratic two-way interaction (step 3)												
$Autonomy^2$							− 0.116	0.177	− 0.542	2.418	1.232	11.300 +
$Autonomy^2$ * cognitive demands							0.376	0.244	2.401	0.811	0.320	5.183*
Cubic two-way interaction (step 4)												
$Autonomy^3$										− 0.279	0.134	− 6.942*
$Autonomy^3$ * cognitive demands												
R^2			0.003			0.113			0.126			0.147
ΔR			0.003			0.110***			0.014			0.021*
F (*df*)			0.556 (1,185)			5.773*** (3,182)			4.336*** (2,180)			4.402*** (1,179)

+ *p*-Wert ≤ .10 **p*-Wert ≤ .05, ***p*-Wert ≤ .01, ****p*-Wert ≤ .001. Cognitive Demands = Cluster of participants with high (1) and lower/medium (0) cognitive demands

Table 7 Hierarchical moderated regression analyses predicting cognitive irritation

	Step 1 (control variables)			Step 2 (linear effects)			Step 3 (quadratic effects)			Step 4 (cubic effects)		
	B	SE	β	B	SE	β	B	SE	β	B	SE	β
Control variable (step 1)												
Age	0.022	0.009	0.174*	0.021	0.009	0.169*	0.022	0.009	0.173*	0.021	0.009	0.172*
Main effects and linear two-way interaction (step 2)												
Autonomy				− 0.341	0.241	− 0.172	− 1.932	1.480	− 0.975	− 10.332	5.060	− 5.212*
Cognitive demands				0.659	1.012	0.193	6.554	3.652	1.917 +	12.314	4.921	3.602*
Autonomy * cognitive demands				0.062	0.313	0.068	− 3.005	2.243	− 3.289	− 6.496	3.004	− 7.110*
Quadratic two-way interaction (step 3)												
Autonomy^2							0.268	0.246	0.898	3.221	1.719	10.778 +
Autonomy^2 * cognitive demands							0.381	0.339	1.745	0.888	0.446	4.063*
Cubic two-way interaction (step 4)												
Autonomy^3										− 0.325	0.187	− 5.792 +
Autonomy^3 * cognitive demands												
R^2			0.030			0.085			0.128			0.142
ΔR			0.030*			0.054*			0.043*			0.014 +
F (df)			5.840* (1,186)			4.243** (3,183)			4.423*** (2,181)			4.263*** (1,180)

+ p-Wert ≤ .10, *p-Wert ≤ .05, **p-Wert ≤ .01, ***p-Wert ≤ .001. Cognitive Demands = Cluster of participants with high (1) and lower/medium (0) cognitive demands

Table 8 Hierarchical moderated regression analyses predicting workability index

	Step 1 (control variables)			Step 2 (linear effects)			Step 3 (quadratic effects)			Step 4 (cubic effects)		
	B	SE	*β*	*B*	SE	*β*	*B*	SE	*β*	*B*	SE	β
Control variable (step 1)												
Age	− 0.002	0.004	− 0.036	− 0.003	0.004	− 0.048	− 0.003	0.004	− 0.049	− 0.003	0.004	− 0.048
Main effects and linear two-way interaction (step 2)												
Autonomy				0.279	0.101	0.333**	0.744	0.636	0.888	2.790	2.187	3.330
Cognitive demands				− 0.013	0.426	− 0.009	− 0.082	1.570	− 0.057	− 1.485	2.127	− 1.028
Autonomy * cognitive demands				− 0.018	0.132	− 0.048	− 0.078	0.964	− 0.202	0.772	1.299	2.000
Quadratic two-way interaction (step 3)												
Autonomy^2							− 0.078	0.106	− 0.621	− 0.797	0.743	− 6.315
Autonomy^2 * cognitive demands							0.022	0.146	0.237	− 0.101	0.193	− 1.099
Cubic two-way interaction (step 4)												
Autonomy^3										0.079	0.081	3.339
Autonomy^3 * cognitive demands												
R^2			0.001			0.093			0.098			0.102
ΔR			0.001			0.092***			0.004			0.005
F (*df*)			0.242 (1,186)			4.705*** (3,183)			3.261** (2,181)			2.931** (1,180)

+ *p*-Wert ≤ .10 **p*-Wert ≤ .05, ***p*-Wert ≤ .01, ****p*-Wert ≤ .001. Cognitive Demands = Cluster of participants with high (1) and lower/medium (0) cognitive demands

Table 9 Hierarchical moderated regression analyses predicting well-being

	Step 1 (control variables)			Step 2 (linear effects)			Step 3 (quadratic effects)			Step 4 (cubic effects)		
	B	SE	*β*	*B*	SE	*β*	*B*	SE	*β*	*B*	SE	*β*
Control variable (step 1)												
Age	0.012	0.007	0.136 +	0.011	0.006	0.123 +	0.011	0.006	0.122 +	0.011	0.006	0.123 +
Main effects and linear two-way interaction (step 2)												
Autonomy				0.418	0.175	0.291*	− 0.373	1.095	− 0.259	4.404	3.758	3.065
Cognitive demands				0.430	0.734	0.173	− 2.391	2.705	− 0.964	− 5.670	3.657	− 2.286
Autonomy * cognitive demands				− 0.106	0.227	− 0.160	1.693	1.661	2.555	3.681	2.233	5.554
Quadratic two-way interaction (step 3)												
Autonomy^2							0.133	0.182	0.615	− 1.546	1.277	− 7.137
Autonomy^2 * cognitiv							− 0.274	0.251	− 1.730	− 0.562	0.332	− 3.551
Cubic two-way interaction (step 4)												
Autonomy^3										0.185	0.139	4.544
Autonomy^3 * cognitive demands												
R^2			0.018			0.090			0.096			0.105
ΔR			0.018+			0.072**			0.006			0.009
F (*df*)			3.484+(1,185)			4.508** (3,182)			3.191** (2,180)			2.999** (1,179)

+ *p*-Wert ≤ .10 **p*-Wert ≤ .05, ***p*-Wert ≤ .01, ****p*-Wert ≤ .001. Cognitive Demands = Cluster of participants with high (1) and lower/medium (0) cognitive demands

Facets of autonomy and health outcomes

Activity latitude

Using activity latitude as an independent variable, there were neither significant regression weights nor significant models for the health outcomes emotional exhaustion, cynicism, and well-being.

The first model is significant for cognitive irritation (F (1,186) = 5.840, $p < 0.05$) (see Appendix Table 13). The relation to the control variable age is significant ($\beta = 0.174$, $p < 0.05$).

Linear effects with activity latitude were only found for workability ($\beta = 0.310$, $p < 0.01$) (see Appendix Table 14). Quadratic effects were not found for any of the health outcomes. Cubic effects of activity latitude are only found for anxiety ($\beta = -8.525$, $p < 0.05$). This fourth model is significant (F (1,179) = 2.819, $p < 0.01$) (see Appendix Table 12).

Design latitude

When design latitude is used as the independent variable, neither significant models nor significant regression weights are found for the outcomes emotional exhaustion, cynicism, workability, and cognitive irritation. In addition to the effect of the control variable age on cognitive irritation, linear effects with design latitude are only found for well-being ($\beta = 0.334$, $p < 0.01$); this second model is significant (F (3,182) = 5.217; $p < 0.001$) (see Appendix Table 21).

Analogous to activity latitude, there are no significant quadratic effects. Cubic effects with design latitude and the entire fourth model are significant for anxiety ($\beta = -5.277$, $p < 0.05$; F (1,179) = 3.698; $p < 0.001$) (see Appendix Table 18).

Decision latitude

Using decision latitude as an independent variable, no significant models or regression weights are found for cynicism and well-being.

Linear effects with decision latitude and significant second models are found for emotional exhaustion ($\beta = -0.283$, $p < 0.05$; (F (3,183) = 3.449; $p < 0.05$) (see Appendix Table 22), anxiety ($\beta = -0.276$, $p < 0.05$; F (3,182) = 5.786; $p < 0.001$) (see Appendix Table 24), and workability ($\beta = 0.356$; $p < 0.01$; F (3,183) = 3.023; $p < 0.05$) (see Appendix Table 26).

Beyond that, however, neither quadratic nor cubic effects of decision latitude can be found between decision latitude and health outcomes.

Discussion

The present study investigated whether the level of task-related cognitive demands moderates the influence of autonomy on employees' health. Autonomy was examined both as an overall construct and in its three dimensions of latitude to act, design, and decide. Task-related cognitive demands were operationalized with two clusters consisting of knowledge and mental demands as well as skill variety, information processing, problem solving, and complexity.

Our first hypothesis, a positive linear relationship between autonomy and various health outcomes such as emotional exhaustion, was confirmed, following the findings of many other studies (e.g., Van Rysselveldt et al., 2011). This result is evident in both the results of our correlation analysis and those of our regression analyses. Workability and well-being were the only two health outcomes to show purely linear correlations. Our data show that an increase in autonomy and its facets is consistent with an increase in workability and well-being. Workability is surveyed in the context of other work demands, health status, and employee resources and thus also covers the individual prerequisites for performance (Ilmarinen 2007). The findings on well-being mirror those of other studies in this context (e.g., Cheung et al. 2015).

We found no evidence for our second hypothesis, that the level of task-related cognitive demands moderates any positive effect found. It is true that our analysis with hierarchical moderated regression analyses showed curvilinear (cubic) effects of autonomy on individual health outcomes. However, the effects and trajectories found were similar to those of other studies (e.g., Stiglbauer 2017), and we did not detect moderation by the level of task-related cognitive demands in any model. Additionally, no significant main effects were found for task-related cognitive demands.

For employees with high task-related cognitive demands, we expected nonlinear relationships with autonomy and health. What was surprising for us was that indications of a nonlinear relationship were also found for low and medium cognitive demands. Our assumption that high task-related cognitive demands act as a kind of reinforcer "on top" and reverse a positive effect of autonomy must therefore be rejected. One reason for this could be that other mechanisms of impact are present when non-linear relationships emerge even without complementary task-related cognitive demands. To understand these results, Karasek's definition of job control can be used. In the present study, various groups of people with different skills and education were examined. Crucial for the effect of job control is the match of decision latitude and intellectual discretion (Karasek 1979).

Our third hypothesis was confirmed to the extent that we had divergent results for the individual facets. Overall, however, we did not find any moderating influence of task-related cognitive requirements. An increase in decision-making latitude consistently showed an increase in health. Especially the assumption that decision latitude with the potentially highest task-related cognitive demands would lead to a tendency to overstrain and health impairment could not be confirmed. Decision-making latitude offers employees wide-ranging opportunities, as they can set their own tasks and task objectives. Again, a reference to Karasek (1979) shows that the match between decision authority and skill level is essential. Such a fit significantly reduces the possibility of overdemanding freedom.

The facet of design latitude describes, that when performing activities, employees can both contribute and develop their own ideas as well as implement them. Contrary to our expectation, we found nonlinear associations with health outcomes for this facet. For instance, emotional exhaustion, cynicism and cognitive irritation as well as anxiety are health outcomes that do not necessarily improve with more design latitude. A great deal of design latitude can be associated with risk and disrupts routine processes (Dewett 2006; Zhou and Hoever 2014). A structural lack of regulations and guidelines makes designing mandatory and thus entails an expanded effort in the form of structuring and planning (Bredehöft et al. 2015). This can add up to increased demands for self-organization and many new work requirements (Allvin et al. 2011; Höge 2011; Sichler 2006; Kubicek et al. 2014), which are then reflected in the nonlinear effects on health parameters.

In addition to the reasons for our findings already presented, there is a possible more general reason that is particularly suitable to explain the more or less consistent curvilinear and missing moderator effects. The general level of reported task-related cognitive demands in the sample is, in line with other research on cognitive demands in the modern world of work (Meyer and Hünefeld 2018), mostly average to high (see Fig. 1). Although the differences between the used moderator groups is quite clear, it could be that the assumed mechanism of overtaxed cognition already starts far below the applied threshold. Accordingly, both groups studied would be subject to it. This could explain the curvilinear correlations without moderation. Since we wanted to make overarching statements about the relationship between autonomy and task-related cognitive demands, we broadly defined the health outcomes, and differential findings emerged in the various domains. For workability and well-being, there was a linear increase with increasing autonomy. Emotional exhaustion and cynicism, on the other hand, did not necessarily decrease with increasing autonomy. These types of results confirm the approach we have taken to analyze a wide range of health outcomes. It becomes clear that positive and negative outcomes are to be evaluated differently. Positive outcomes show positive correlations with autonomy, that is, a strengthening of health, but this is not the same as a decrease in negative outcomes, that is, an improvement in health impairment.

In the case of cognitive irritation and anxiety, tendencies for quadratic and cubic effects of design and activity latitude were found. One explanation could be that employees lack the skills or knowledge to be able to use the latitude (Sichler 2006), and this lack leads to poorer mental health. It is also possible that there is a lack of a structured framework, for example, in the form of organizational conditions or social support, in which they can meet the demands (Dettmers and Bredehöft, 2020; Egan et al. 2007). If employees themselves have to make new decisions about structures, procedures, and processes, this can lead to excessive demands (Egan et al. 2007). High autonomy in the form of shifting entrepreneurial responsibility to the employees themselves requires a psychologically demanding form of self-organization and self-optimization (Niehaus 2012; Sparks et al. 2001), which can result in cognitive irritation (Dettmers and Bredehöft 2020). The negative consequences of this are especially noticeable when mistakes happen or wrong decisions are made (Lehner et al. 2013). In this context, anxiety is an important health outcome that has received too little attention so far. Fear of being wrong or making the wrong decision is highly relevant in the subjectification and self-optimization tendencies prevalent in the new world of work. This corresponds exactly to the way the concept of autonomy is located in the individual by research and the world of work (for example, Sichler 2006; Moldaschl and Voß, 2002). This perception of autonomy as a requirement for the individual makes the use of health outcomes such as anxiety necessary.

Limitations

First of all, our study has a cross-sectional design, that is, we did not collect longitudinal data that would allow us to draw conclusions about developments over time. For the measurement of the independent variable autonomy and the moderator task-related cognitive demands this should not pose a problem as both come into effect at the same time. However, effects on health need some time to develop and a second measurement time would have been preferable. Nevertheless, due to the long duration of employment the participants reported in the same SME, it could be argued that at least part of developments are captured in the data. Moreover, our results are not based on objective data but on self-reports. Due to common method bias observed relationships could be inflated or deflated depending on the question whether correlation between methods is higher or lower than the observed correlation without common methods (Podsakoff et al. 2003). Results show small to medium-sized correlations between the variable groups in question (autonomy, task-related cognitive demands and health outcomes) so that inflation probability is rather low. In addition, existing quadratic or interaction effects are deflated by common method variance (Siemsen et al. 2010) making them harder to detect. Work characteristics as well as cognitive demands are objective environmental factors but need to be internally processed. Again, it is difficult to collect these variables using objective methods, such as workplace observation. The collection of physiological health parameters could have been an enrichment for our results.

By clustering the different aspects of task-related cognitive demands, we succeeded in covering a broad range of possible influences and thus did not form an isolated moderator. However, we cannot exclude the possibility that other influences or requirements are relevant. Another limitation may be the sample per se. On the one hand, the response rate is on the low side of average response rates in applied contexts (Anseel et al. 2010; Baruch and Holtom 2008; Weigold et al. 2019) driven by factors in the companies we could not change. Nevertheless, sample size is sufficient for the performed analyses to find even small effects with a power of 0.90 (G*Power, Faul et al. 2009). On the other hand, due to the different response rates in the participating companies, sample attrition cannot be excluded. Although we were able to include three different companies and different occupational groups, it is not possible to generalize the results due to the small sample. In addition, the clustering of employees into those with high cognitive demands and those with lower cognitive demands shows a strong bias toward male study participants. On the other hand, the large proportion of men in the group with high cognitive demands is related to the still widespread social reality that men are more likely to hold positions and jobs that make such demands.

Conclusions

Due to its positive effect on the health of employees, autonomy is an essential component of workplace design that promotes health and personality. In addition, this study illustrates that even well-known resources such as autonomy should always be considered in an organizational and social context.

Appendix

See Tables 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27.

Table 10 Hierarchical moderated regression analyses predicting emotional exhaustion

	B	SE	*β*	*B*	SE	*β*	*B*	SE	*β*	*B*	SE	*β*
Control variable (step 1)												
Age	0.006	0.007	0.064	0.005	0.007	0.051	0.004	0.007	0.047	0.004	0.007	0.043
Main effects and linear two-way interaction (step 2)												
Acitivity latitude				− 0.181	0.161	− 0.130	− 1.245	1.280	− 0.890	− 8.617	4.867	− 6.160 +
Cognitive demands				0.697	0.827	0.270	2.086	3.367	0.809	4.950	3.817	1.919
Acitivity latitude * cognitive demands				− 0.094	0.214	− 0.155	− 0.693	1.861	− 1.147	− 2.261	2.106	− 3.743
Quadratic two-way interaction (step 3)												
Acitivity latitude^2							0.151	0.180	0.805	2.409	1.450	12.863 +
Acitivity latitude^2 * cognitive demands							0.062	0.249	0.483	0.267	0.280	2.060
Cubic two-way interaction (step 4)												
Acitivity latitude^3										− 0.219	0.140	− 6.877
Acitivity latitude^3 * cognitive demands												
R^2			0.004			0.038			0.049			0.062
ΔR			0.004			0.034 +			0.012			0.013
F (*df*)			0.753 (1,186)			1.792 (3,183)			1.568 (2,181)			1.707 (1,180)

+ *p*-Wert ≤ .10 **p*-Wert ≤ .05, ***p*-Wert ≤ .01, ****p*-Wert ≤ .001. Cognitive Demands = Cluster of participants with high (1) and lower/medium (0) cognitive demands

Table 11 Hierarchical moderated regression analyses predicting cynicism

	B	SE	*β*	*B*	SE	*β*	*B*	SE	*β*	*B*	SE	*β*
Control variable (step 1)												
Age	− 0.008	0.007	− 0.083	− 0.009	0.007	− 0.093	− 0.009	0.007	− 0.095	− 0.009	0.007	− 0.095
Main effects and linear two-way interaction (step 2)												
Acitivity latitude				− 0.247	0.163	− 0.174	− 1.073	1.310	− 0.759	− 0.916	4.993	− 0.648
Cognitive demands				0.273	0.837	0.104	0.359	3.430	0.137	0.297	3.931	0.113
Acitivity latitude * cognitive demands				− 0.040	0.217	− 0.065	0.024	1.897	0.039	0.058	2.171	0.095
Quadratic two-way interaction (step 3)												
Acitivity latitude^2							0.117	0.184	0.618	0.069	1.490	0.364
Acitivity latitude^2 * cognitive demands							− 0.019	0.254	− 0.146	− 0.024	0.289	− 0.180
Cubic two-way interaction (step 4)												
Acitivity latitude^3										0.005	0.144	0.145
Acitivity latitude^3 * cognitive demands												
R^2			0.007			0.040			0.044			0.044
ΔR			0.007			0.033			0.004			0.000
F (*df*)			1.287 (1,185)			1.901 (3,182)			1.378 (2,180)			1.175 (1,179)

+*p*-Wert ≤ .10 **p*-Wert ≤ .05, ***p*-Wert ≤ .01, ****p*-Wert ≤ .001. Cognitive Demands = Cluster of participants with high (1) and lower/medium (0) cognitive demands

Table 12 Hierarchical moderated regression analyses predicting anxiety

	B	SE	*β*	*B*	SE	*β*	*B*	SE	*β*	*B*	SE	*β*
Control variable (step 1)												
Age	− 0.005	0.007	− 0.055	− 0.005	0.006	− 0.052	− 0.005	0.006	− 0.055	− 0.005	0.006	− 0.060
Main effects and linear two-way interaction (step 2)												
Acitivity latitude				− 0.071	0.150	− 0.053	0.961	1.199	0.723	− 7.716	4.544	− 5.809 +
Cognitive demands				0.668	0.774	0.273	4.689	3.159	1.913	8.048	3.564	3.283*
Acitivity latitude * cognitive demands				− 0.266	0.200	− 0.463	− 2.544	1.746	− 4.433	− 4.383	1.966	− 7.637*
Quadratic two-way interaction (step 3)												
Acitivity latitude^2							− 0.146	0.169	− 0.823	2.511	1.354	14.125 +
Acitivity latitude^2 * cognitive demands							0.306	0.234	2.491	0.546	0.262	4.438*
Cubic two-way interaction (step 4)												
Acitivity latitude^3										− 0.258	0.130	− 8.525*
Acitivity latitude^3 * cognitive demands												
R^2			0.003			0.071			0.080			0.099
ΔR			0.003			0.068**			0.009			0.020*
F (*df*)			0.556 (1,185)			3.466** (3,182)			2.595* (2,180)			2.819** (1,179)

+*p*-Wert ≤ .10 **p*-Wert ≤ .05, ***p*-Wert ≤ .01, ****p*-Wert ≤ .001. Cognitive Demands = Cluster of participants with high (1) and lower/medium (0) cognitive demands

Table 13 Hierarchical moderated regression analyses predicting cognitive irritation

	B	SE	*β*	*B*	SE	*β*	*B*	SE	*β*	*B*	SE	*β*
Control variable (step 1)												
Age	0.021	0.009	0.174*	0.019	0.009	0.156*	0.019	0.009	0.155*	0.019	0.009	0.151*
Main effects and linear two-way interaction (step 2)												
Acitivity latitude				− 0.231	0.206	− 0.125	− 0.216	1.648	− 0.117	− 8.469	6.275	− 4.566
Cognitive demands				1.707	1.058	0.499	3.108	4.333	0.909	6.313	4.921	1.846
Acitivity latitude * cognitive demands				− 0.232	0.274	− 0.290	− 0.980	2.395	− 1.224	− 2.735	2.715	− 3.416
Quadratic two-way interaction (step 3)												
Acitivity latitude^2							− 0.002	0.232	− 0.009	2.525	1.869	10.171
Acitivity latitude^2 * cognitive demands							0.096	0.321	0.560	0.325	0.361	1.892
Cubic two-way interaction (step 4)												
Acitivity latitude^3										− 0.245	0.180	− 5.806
Acitivity latitude^3 * cognitive demands												
R^2			0.030			0.103			0.104			0.113
ΔR			0.030*			0.073**			0.001			0.009
F (*df*)			5.840* (1,186)			5.277*** (3,183)			3.513** (2,181)			3.291** (1,180)

+*p*-Wert ≤ .10 **p*-Wert ≤ .05, ***p*-Wert ≤ .01, ****p*-Wert ≤ .001. Cognitive Demands = Cluster of participants with high (1) and lower/medium (0) cognitive demands

Table 14 Hierarchical moderated regression analyses predicting Workability Index

	B	SE	*β*	*B*	SE	*β*	*B*	SE	*β*	*B*	SE	*β*
Control variable (step 1)												
Age	− 0.002	0.004	− 0.036	− 0.001	0.004	− 0.026	− 0.001	0.004	− 0.026	− 0.001	0.004	− 0.023
Main effects and linear two-way interaction (step 2)												
Acitivity latitude				0.243	0.089	0.310**	0.310	0.710	0.395	3.573	2.705	4.559
Cognitive demands				0.301	0.456	0.208	0.227	1.866	0.157	− 1.040	2.121	− 0.720
Acitivity latitude * cognitive demands				− 0.077	0.118	− 0.229	− 0.047	1.032	− 0.139	0.647	1.170	1.912
Quadratic two-way interaction (step 3)												
Acitivity latitude^2							− 0.009	0.100	− 0.090	− 1.009	0.806	− 9.617
Acitivity latitude^2 * cognitive demands							− 0.003	0.138	− 0.041	− 0.093	0.156	− 1.287
Cubic two-way interaction (step 4)												
Acitivity latitude^3										0.097	0.078	5.433
Acitivity latitude^3 * cognitive demands												
R^2			0.001			0.069			0.069			0.077
ΔR			0.001			0.068**			0.000			0.008
F (*df*)			0.242 (1,186)			3.404* (3,183)			2.249* (2,181)			2.157* (1,180)

+*p*-Wert ≤ .10 **p*-Wert ≤ .05, ***p*-Wert ≤ .01, ****p*-Wert ≤ .001. Cognitive Demands = Cluster of participants with high (1) and lower/medium (0) cognitive demands

Table 15 Hierarchical moderated regression analyses predicting well-being

	B	SE	*β*	*B*	SE	*β*	*B*	SE	*β*	*B*	SE	*β*
Control variable (step 1)												
Age	0.012	0.007	0.136 +	0.012	0.007	0.135 +	0.012	0.007	0.133 +	0.012	0.007	0.133 +
Main effects and linear two-way interaction (step 2)												
Acitivity latitude				0.186	0.154	0.138	− 1.291	1.227	− 0.960	− 2.130	4.698	− 1.584
Cognitive demands				0.436	0.791	0.176	− 1.058	3.231	− 0.426	− 0.733	3.684	− 0.296
Acitivity latitude * cognitive demands				− 0.046	0.205	− 0.079	0.945	1.786	1.627	0.767	2.033	1.321
Quadratic two-way interaction (step 3)												
Acitivity latitude^2							0.209	0.173	1.163	0.466	1.399	2.592
Acitivity latitude^2 * cognitive demands							− 0.147	0.239	− 1.182	− 0.124	0.271	− 0.996
Cubic two-way interaction (step 4)												
Acitivity latitude^3										− 0.025	0.135	− 0.815
Acitivity latitude^3 * cognitive demands												
R^2			0.018			0.052			0.060			0.060
ΔR			0.018 +			0.033			0.008			0.000
F (*df*)			3.484 + (1,185)			2.474* (3,182)			1.914 + (2,180)			1.637 (1,179)

+ *p*-Wert ≤ .10 **p*-Wert ≤ .05, ***p*-Wert ≤ .01, ****p*-Wert ≤ .001. Cognitive Demands = Cluster of participants with high (1) and lower/medium (0) cognitive demands

Table 16 Hierarchical moderated regression analyses predicting emotional exhaustion

	B	SE	*β*	*B*	SE	*β*	*B*	SE	*β*	*B*	SE	*β*
Control variable (step 1)												
Age	0.006	0.007	0.064	0.007	0.007	0.073	0.007	0.007	0.070	0.006	0.007	0.068
Main effects and linear two-way interaction (step 2)												
Design latitude				− 0.201	0.136	− 0.183	− 1.303	0.658	− 1.182*	− 2.461	1.820	− 2.233
Cognitive demands				0.638	0.552	0.247	− 1.178	1.432	− 0.457	− 0.350	1.877	− 0.136
Design latitude * cognitive demands				− 0.069	0.176	− 0.103	1.392	0.965	2.080	0.847	1.254	1.266
Quadratic two-way interaction (step 3)												
Design latitude^2							0.200	0.117	1.144 +	0.659	0.681	3.762
Design latitude^2 * cognitive demands							− 0.253	0.155	− 1.698	− 0.171	0.197	− 1.146
Cubic two-way interaction (step 4)												
Design latitude^3										− 0.054	0.079	− 1.620
Design latitude^3 * cognitive demands												
R^2			0.004			0.053			0.069			0.072
ΔR			0.004			0.049*			0.016			0.002
F (*df*)			0.753 (1,186)			2.557* (3,183)			2.247* (2,181)			1.987 + (1,180)

+ *p*-Wert ≤ .10 **p*-Wert ≤ .05, ***p*-Wert ≤ .01, ****p*-Wert ≤ .001. Cognitive Demands = Cluster of participants with high (1) and lower/medium (0) cognitive demands

Table 17 Hierarchical moderated regression analyses predicting cynicism

	B	SE	*β*	*B*	SE	*β*	*B*	SE	*β*	*B*	SE	*β*
Control variable (step 1)												
Age	− 0.008	0.007	− 0.083	− 0.007	0.007	− 0.073	− 0.007	0.007	− 0.076	− 0.008	0.007	− 0.081
Main effects and linear two-way interaction (step 2)												
Design latitude				− 0.227	0.140	− 0.203	− 0.897	0.680	− 0.803	− 3.890	1.878	− 3.481*
Cognitive demands				− 0.096	0.568	− 0.036	− 1.372	1.476	− 0.523	0.758	1.926	0.289
Design latitude * cognitive demands				0.078	0.180	0.115	1.077	0.996	1.586	− 0.318	1.284	− 0.468
Quadratic two-way interaction (step 3)												
Design latitude^2							0.122	0.121	0.688	1.305	0.703	7.352 +
Design latitude^2 * cognitive demands							− 0.170	0.161	− 1.127	0.040	0.202	0.263
Cubic two-way interaction (step 4)												
Design latitude^3										− 0.138	0.081	− 4.121 +
Design latitude^3 * cognitive demands												
R^2			0.007			0.030			0.037			0.052
ΔR			0.007			0.023			0.007			0.015 +
F (*df*)			1.287 (1,185)			1.406 (3,182)			1.137 (2,180)			1.402 (1,179)

+ *p*-Wert ≤ .10 **p*-Wert ≤ .05, ***p*-Wert ≤ .01, ****p*-Wert ≤ .001. Cognitive Demands = Cluster of participants with high (1) and lower/medium (0) cognitive demands

Table 18 Hierarchical moderated regression analyses predicting anxiety

	B	SE	*β*	*B*	SE	*β*	*B*	SE	*β*	*B*	SE	*β*
Control variable (step 1)												
Age	− 0.005	0.00	− 0.055	− 0.00	0.006	− 0.031	− 0.002	0.006	− 0.023	− 0.002	0.006	− 0.028
Main effects and linear two-way interaction (step 2)												
Design latitude				− 0.172	0.127	− 0.165	− 0.091	0.616	− 0.087	− 3.674	1.681	− 3.511*
Cognitive demands				0.110	0.517	0.045	2.062	1.341	0.841	4.623	1.735	1.886**
Design latitude * cognitive demands				− 0.117	0.164	− 0.184	− 1.377	0.905	− 2.166	− 3.063	1.159	− 4.818**
Quadratic two-way interaction (step 3)												
Design latitude^2							− 0.015	0.110	− 0.089	1.403	0.629	8.439*
Design latitude^2 * cognitive demands							0.188	0.146	1.327	0.442	0.182	3.124*
Cubic two-way interaction (step 4)												
Design latitude^3										− 0.166	0.073	− 5.277*
Design latitude^3 * cognitive demands												
R^2			0.003			0.085			0.101			0.126
ΔR			0.003			0.082***			0.016			0.026*
F (*df*)			0.556 (1,185)			4.202** (3,182)			3.364** (2,180)			3.698*** (1,179)

+ *p*-Wert ≤ .10 **p*-Wert ≤ .05, ***p*-Wert ≤ .01, ****p*-Wert ≤ .001. Cognitive Demands = Cluster of participants with high (1) and lower/medium (0) cognitive demands

Table 19 Hierarchical moderated regression analyses predicting cognitive irritation

	B	SE	*β*	*B*	SE	*β*	*B*	SE	*β*	*B*	SE	*β*
Control variable (step 1)												
Age	0.022	0.009	0.174*	0.021	0.009	0.172*	0.022	0.009	0.174*	0.022	0.009	0.174*
Main effects and linear two-way interaction (step 2)												
Design latitude				− 0.123	0.178	− 0.084	− 1.548	0.861	− 1.059 +	− 1.562	2.384	− 1.069
Cognitive demands				0.978	0.723	0.286	0.513	1.873	0.150	0.523	2.460	0.153
Design latitude * cognitive demands				− 0.067	0.230	− 0.075	0.631	1.263	0.711	0.624	1.643	0.704
Quadratic two-way interaction (step 3)												
Design latitude^2							0.259	0.153	1.117 +	0.265	0.892	1.140
Design latitude^2 * cognitive demands							− 0.152	0.203	− 0.772	− 0.151	0.258	− 0.767
Cubic two-way interaction (step 4)												
Design latitude^3										− 0.001	0.103	− 0.015
Design latitude^3 * cognitive demands												
R^2			0.030			0.076			0.094			0.094
ΔR			0.030*			0.046*			0.018			0.000
F (*df*)			5.840* (1,186)			3.763** (3,183)			3.112** (2,181)			2.653* (1,180)

+ *p*-Wert ≤ .10 **p*-Wert ≤ .05, ***p*-Wert ≤ .01, ****p*-Wert ≤ .001. Cognitive Demands = Cluster of participants with high (1) and lower/medium (0) cognitive demands

Table 20 Hierarchical moderated regression analyses predicting workability index

	B	SE	*β*	*B*	SE	*β*	*B*	SE	*β*	*B*	SE	*β*
Control variable (step 1)												
Age	− 0.002	0.004	− 0.036	− 0.003	0.004	− 0.058	− 0.003	0.004	− 0.059	− 0.003	0.004	− 0.057
Main effects and linear two-way interaction (step 2)												
Design latitude				0.117	0.075	0.190	− 0.103	0.366	− 0.166	0.589	0.004	− 0.057
Cognitive demands				− 0.311	0.305	− 0.215	− 0.677	0.797	− 0.468	− 1.171	1.045	− 0.810
Design latitude * cognitive demands				0.094	0.097	0.250	0.387	0.537	1.033	0.712	0.698	1.901
Quadratic two-way interaction (step 3)												
Design latitude^2							0.040	0.065	0.407	− 0.234	0.379	− 2.381
Design latitude^2 * cognitive demands							− 0.051	0.087	− 0.608	− 0.100	0.110	− 1.196
Cubic two− way interaction (step 4)												
Design latitude^3										0.032	0.044	1.726
Design latitude^3 * cognitive demands												
R^2			0.001			0.079			0.081			0.084
ΔR			0.001			0.078**			0.002			0.003
F (*df*)			0.242 (1,186)			3.941** (3,183)			2.673* (2,181)			2.362* (1,180)

+ *p*-Wert ≤ .10 **p*-Wert ≤ .05, ***p*-Wert ≤ .01, ****p*-Wert ≤ .001. Cognitive Demands = Cluster of participants with high (1) and lower/medium (0) cognitive demands

Table 21 Hierarchical moderated regression analyses predicting well-being

	B	SE	β	B	SE	β	B	SE	β	B	SE	β
Control variable (step 1)												
Age	0.012	0.007	0.136 +	0.010	0.006	0.114	0.010	0.006	0.112	0.010	0.006	0.113
Main effects and linear two-way interaction (step 2)												
Design latitude				0.354	0.128	0.334**	0.467	0.622	0.441	1.474	1.721	1.392
Cognitive demands				0.419	0.518	0.169	0.032	1.355	0.013	− 0.688	1.777	− 0.277
Design latitude * cognitive demands				− 0.112	0.165	− 0.174	0.102	0.914	0.159	0.576	1.187	0.896
Quadratic two-way interaction (step 3)												
Design latitude^2							− 0.021	0.111	− 0.122	− 0.419	0.644	− 2.491
Design latitude^2 * cognitive demands							− 0.027	0.147	− 0.191	− 0.099	0.186	− 0.690
Cubic two-way interaction (step 4)												
Design latitude^3										0.047	0.074	1.466
Design latitude^3 * cognitive demands												
R^2			0.018			0.103			0.104			0.106
ΔR			0.018 +			0.084***			0.001			0.002
F (df)			3.484 + (1,185)			5.217*** (3,182)			3.492** (2,180)			3.039** (1,179)

+ p-Wert ≤ .10 *p-Wert ≤ .05, **p-Wert ≤ .01, ***p-Wert ≤ .001. Cognitive Demands = Cluster of participants with high (1) and lower/medium (0) cognitive demands

Table 22 Hierarchical moderated regression analyses predicting emotional exhaustion

	B	SE	β	B	SE	β	B	SE	β	B	SE	β
Control variable (step 1)												
Age	0.006	0.007	0.064	0.007	0.007	0.071	0.007	0.007	0.071	0.007	0.007	0.070
Main effects and linear two-way interaction (step 2)												
Decision latitude				− 0.368	0.171	− 0.283*	− 0.669	0.766	− 0.514	− 1.942	1.724	− 1.493
Cognitive demands				0.312	0.586	0.121	0.218	1.460	0.085	0.793	1.619	0.307
Decision latitude * cognitive demands				0.049	0.209	0.065	0.180	1.029	0.240	− 0.232	1.145	− 0.310
Quadratic two-way interaction (step 3)												
Decision latitude^2							0.057	0.141	0.267	0.571	0.639	2.684
Decision latitude^2 * cognitive demands							− 0.030	0.175	− 0.169	0.037	0.194	0.203
Cubic two-way interaction (step 4)												
Decision latitude^3										− 0.062	0.075	− 1.495
Decision latitude^3 * cognitive demands												
R^2			0.004			0.070			0.071			0.075
ΔR			0.004			0.066**			0.001			0.003
F (df)			0.753 (1,186)			3.449* (3,183)			2.315* (2,181)			2.078* (1,180)

+ p-Wert ≤ .10 *p-Wert ≤ .05, **p-Wert ≤ .01, ***p-Wert ≤ .001. Cognitive Demands = Cluster of participants with high (1) and lower/medium (0) cognitive demands

Table 23 Hierarchical moderated regression analyses predicting cynicism

	B	SE	*β*	*B*	SE	*β*	*B*	SE	*β*	*B*	SE	*β*
Control variable (step 1)												
Age	− 0.008	0.007	− 0.083	− 0.007	0.007	− 0.075	− 0.008	0.007	− 0.079	− 0.008	0.007	− 0.081
Main effects and linear two-way interaction (step 2)												
Decision latitude				− 0.338	0.175	− 0.257 +	− 0.152	0.787	− 0.115	− 1.596	1.769	− 1.213
Cognitive demands				− 0.156	0.602	− 0.059	− 1.308	1.495	− 0.499	− 0.660	1.656	− 0.252
Decision latitude * cognitive demands				0.115	0.215	0.152	0.839	1.055	1.103	0.376	1.172	0.494
Quadratic two-way interaction (step 3)												
Decision latitude^2							− 0.035	0.145	− 0.164	0.547	0.655	2.544
Decision latitude^2 * cognitive demands							− 0.106	0.180	− 0.578	− 0.030	0.198	− 0.165
Cubic two-way interaction (step 4)												
Decision latitude^3										− 0.070	0.077	− 1.673
Decision latitude^3 * cognitive demands												
R^2			0.007			0.043			0.053			0.057
ΔR			0.007			0.036 +			0.009			0.004
F (*df*)			1.287 (1,185)			2.064 + (3,182)			1.675 (2,180)			1.553 (1,179)

+ *p*-Wert ≤ .10 **p*-Wert ≤ .05, ***p*-Wert ≤ .01, ****p*-Wert ≤ .001. Cognitive Demands = Cluster of participants with high (1) and lower/medium (0) cognitive demands

Table 24 Hierarchical moderated regression analyses predicting anxiety

	B	SE	β	B	SE	β	B	SE	β	B	SE	β
Control variable (step 1)												
Age	− 0.005	0.007	− 0.055	− 0.003	0.006	− 0.031	− 0.003	0.006	− 0.030	− 0.002	0.006	− 0.028
Main effects and linear two-way interaction (step 2)												
Decision latitude				− 0.341	0.159	− 0.276*	0.476	0.710	0.385	2.643	1.591	2.140 +
Cognitive demands				− 0.122	0.545	− 0.050	0.578	1.353	0.236	− 0.401	1.494	− 0.164
Decision latitude * cognitive demands				− 0.032	0.195	− 0.046	− 0.683	0.954	− 0.960	0.020	1.057	0.028
Quadratic two-way interaction (step 3)												
Decision latitude^2							− 0.154	0.131	− 0.763	− 1.029	0.590	− 5.095 +
Decision latitude^2 * cognitive demands							0.128	0.163	0.750	0.014	0.179	0.081
Cubic two-way interaction (step 4)												
Decision latitude^3										0.105	0.069	2.678
Decision latitude^3 * cognitive demands												
R^2			0.003			0.113			0.120			0.131
ΔR			0.003			0.110***			0.007			0.011
F (df)			0.556 (1,185)			5.786*** (3,182)			4.090*** (2,180)			3.861*** (1,179)

+ p-Wert ≤ .10 *p-Wert ≤ .05, **p-Wert ≤ .01, ***p-Wert ≤ .001. Cognitive Demands = Cluster of participants with high (1) and lower/medium (0) cognitive demands

Table 25 Hierarchical moderated regression analyses predicting cognitive irritation

	B	SE	*β*	*B*	SE	*β*	*B*	SE	*β*	*B*	SE	*β*
Control variable (step 1)												
Age	0.022	0.009	0.174*	0.020	0.009	0.163*	0.021	0.009	0.167*	0.021	0.009	0.164*
Main effects and linear two-way interaction (step 2)												
Decision latitude				− 0.427	0.225	− 0.248 +	0.372	1.006	0.215	− 2.543	2.253	− 1.474
Cognitive demands				− 0.538	0.771	− 0.157	1.469	1.915	0.430	2.785	2.116	0.814
Decision latitude * cognitive demands				0.474	0.275	0.477 +	− 1.042	1.350	− 1.049	− 1.985	1.496	− 1.999
Quadratic two-way interaction (step 3)												
Decision latitude^2							− 0.151	0.185	− 0.535	1.025	0.835	3.637
Decision Latitude^2 * cognitive demands							0.262	0.230	1.095	0.415	0.253	1.737
Cubic two-way interaction (step 4)												
Decision latitude^3										− 0.142	0.098	− 2.579
Decision latitude^3 * cognitive demands												
R^2			0.030			0.084			0.090			0.101
ΔR			0.030*			0.053*			0.007			0.010
F (*df*)			5.840* (1,186)			4.176** (3,183)			2.993** (2,181)			2.879** (1,180)

+ *p*-Wert ≤ .10 **p*-Wert ≤ .05, ***p*-Wert ≤ .01, ****p*-Wert ≤ .001. Cognitive Demands = Cluster of participants with high (1) and lower/medium (0) cognitive demands

Table 26 Hierarchical moderated regression analyses predicting Workability Index

	B	SE	*β*	*B*	SE	*β*	*B*	SE	*β*	*B*	SE	*β*
Control variable (step 1)												
Age	− 0.002	0.004	− 0.036	− 0.002	0.004	− 0.047	− 0.002	0.004	− 0.042	− 0.002	0.004	− 0.043
Main effects and linear two-way interaction (step 2)												
Decision latitude				0.259	0.096	0.356**	0.756	0.429	1.037 +	0.539	0.967	0.740
Cognitive demands				0.367	0.329	0.254	1.349	0.817	0.934	1.447	0.908	1.001
Decision latitude * cognitive demands				− 0.137	0.118	− 0.325	− 0.902	0.576	− 2.150	− 0.972	0.642	− 2.317
Quadratic two-way interaction (step 3)												
Decision latitude^2							− 0.094	0.079	− 0.787	− 0.006	0.358	− 0.052
Decision latitude^2 * cognitive demands							0.135	0.098	1.340	0.147	0.109	1.453
Cubic two-way interaction (step 4)												
Decision latitude^3										− 0.011	0.042	− 0.454
Decision latitude^3 * cognitive demands												
R^2			0.001			0.062			0.072			0.072
ΔR			0.001			0.061**			0.010			0.000
F (*df*)			0.242 (1,186)			3.023* (3,183)			2.334* (2,181)			1.999 + (1,180)

+ *p*-Wert ≤ .10 **p*-Wert ≤ .05, ***p*-Wert ≤ .01, ****p*-Wert ≤ .001. Cognitive Demands = Cluster of participants with high (1) and lower/medium (0) cognitive demands

Table 27 Hierarchical moderated regression analyses predicting well-being

	B	SE	β	B	SE	β	B	SE	β	B	SE	β
Control variable (step 1)												
Age	0.012	0.007	0.136 +	0.011	0.007	0.122 +	0.011	0.007	0.120 +	0.011	0.007	0.121 +
Main effects and linear two-way interaction (step 2)												
Decision latitude				0.311	0.164	0.249 +	− 0.036	0.738	− 0.029	0.012	1.665	0.009
Cognitive demands				0.504	0.565	0.203	− 0.012	1.406	− 0.005	− 0.034	1.562	− 0.014
Decision Latitude * Cognitive Demands				− 0.117	0.202	− 0.163	0.305	0.991	0.423	0.320	1.105	0.445
Quadratic two-way interaction (step 3)												
Decision latitude^2							0.066	0.136	0.321	0.046	0.617	0.226
Decision latitude^2 * cognitive demands							− 0.077	0.169	− 0.445	− 0.080	0.187	− 0.459
Cubic two-way interaction (step 4)												
Decision latitude^3										0.002	0.073	0.059
Decision Latitude^3 * Cognitive Demands												
R^2			0.018			0.071			0.072			0.072
ΔR			0.018 +			0.052*			0.001			0.000
F (df)			3.484 + (1,185)			3.468** (3,182)			2.331* (2,180)			1.987 + (1,179)

+p-Wert ≤ .10 *p-Wert ≤ .05, **p-Wert ≤ .01, ***p-Wert ≤ .001. Cognitive Demands = Cluster of participants with high (1) and lower/medium (0) cognitive demands

Author contributions Conceptualization: SZ, BH Ideas; formulation or evolution of overarching research goals and aims. Data curation: BH, SZ Management activities to annotate (produce metadata), scrub data and maintain research data (including software code, where it is necessary for interpreting the data itself) for initial use and later reuse. Formal analysis: BH, SZ Application of statistical, mathematical, computational, or other formal techniques to analyze or synthesize study data. Funding acquisition: BH Acquisition of the financial support for the project leading to this publication. Investigation: SZ BH Conducting a research and investigation process, specifically performing the experiments, or data/evidence collection. Methodology: BH SZ Development or design of methodology; creation of models. Project administration: BH Management and coordination responsibility for the research activity planning and execution. Resources: BH Provision of study materials, reagents, materials, patients, laboratory samples, animals, instrumentation, computing resources, or other analysis tools. Software: SPSS Programming, software development; designing computer programs; implementation of the computer code and supporting algorithms; testing of existing code components. Supervision: BH Oversight and leadership responsibility for the research activity planning and execution, including mentorship external to the core team. Validation: BH Verification, whether as a part of the activity or separate, of the overall replication/reproducibility of results/experiments and other research outputs. Visualization: BH, SZ Preparation, creation and/or presentation of the published work, specifically visualization/data presentation. Writing—original draft: SZ Preparation, creation and/or presentation of the published work, specifically writing the initial draft (including substantive translation). Writing—review and editing: BH Preparation, creation and/or presentation of the published work by those from the original research group, specifically critical review, commentary or revision—including pre- or post-publication stages.

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4. Schlussfolgerungen und Ausblick

Für die Arbeitsform der digital vernetzten Arbeit stellt sich die Frage nach der Rolle des Tätigkeitsspielraums auf besondere Art. Denn die digital vernetzte Arbeit ist geprägt von Ambivalenzen (Marsh et al., 2022). Die Möglichkeiten der Digitalisierung können Tätigkeiten erleichtern, aber eben auch erweitern oder eingrenzen (Bawden und Robinson, 2009; D´Arcy et al., 2014; Tarafadar und Stich, 2018). Dadurch verändern sich die Ausprägungen der Arbeitsbedingungen. Vor allem die Bedeutung der kognitiven Anforderungen, wie die Verarbeitung von Informationen und Wissen oder die Fähigkeit zum Problemlösen, ist gestiegen. Die Rolle des Tätigkeitsspielraums kann sich aus diesen veränderten Arbeitsbedingungen und einem komplexen Gesamtgefüge der digital vernetzten Arbeit ebenfalls verändern. Ergänzend dazu haben sich im Zuge der Digitalisierung auch die Erwartungen an die Beschäftigten, beispielsweise bezüglich Selbstorganisation, gewandelt (Sichler, 2006). In diesem Geflecht kann sich dann auch die grundsätzlich positive Auswirkung eines Tätigkeitsspielraums umkehren.

Die Ergebnisse der beiden Publikationen lassen zwei wesentliche Schlussfolgerungen zu, wie diesen Ambivalenzen begegnet werden kann, sodass die Auswirkungen des Tätigkeitsspielraums auf die Beschäftigten positiv bleiben können. Digital vernetzte Arbeit und die Spielräume brauchen zum einen passende und regelmäßige Qualifizierung von Beschäftigten und zum anderen festgelegte organisationale Rahmenbedingungen und Strukturen (Hamburg, 2019; Körner et al., 2019).

Letzteres steht nicht im Widerspruch zur Möglichkeit, flexibel auf Handlungen und Vorgehensweisen Einfluss zu nehmen. Die moderne Arbeitswelt scheint jedoch geprägt von der Vorstellung, dass die Beschäftigten nicht nur die Aufgaben organisieren sollen, sondern auch das Gefüge, in dem sie eingebettet sind (Sichler, 2006). In einem nächsten Schritt führt diese Anforderung und das Fehlen von passenden Strukturen jedoch dazu, dass sie neben den Kenntnissen und Fertigkeiten für ihre Tätigkeit ergänzend Kompetenzen wie das Planen oder Problemlösen mitbringen müssen (Bredehöft et al., 2015).

An dieser Stelle wird die Notwendigkeit der Qualifizierung deutlich. Die digital vernetzte Arbeit erfordert „neue“ Kompetenzen. Es findet eine Verschiebung von spezifischen Fachkenntnissen hin zu persönlichen und sozialen Kompetenzen statt. Im gleichen Zuge müssen auch die digitalen Kompetenzen erworben werden. Hierbei zeigt sich, dass der Bereich der Qualifizierung ebenfalls ambivalent ist. Auf der einen Seite braucht es die erwähnte Vielfalt an Kompetenzen und es werden gesteigerte Qualifikationsanforderungen an die Beschäftigten gestellt, auf der anderen Seite beschränken sich viele Tätigkeiten durch den Einsatz moderner Technologien mittlerweile auf das Überwachen und Kontrollieren von Abläufen und Ergebnissen (Arntz et al., 2016; Arnold et al., 2016).

Doch auch für diese Tätigkeiten scheint es zwingend notwendig, auf regelmäßige Formen der Qualifizierung zu achten, denn die Technologien unterliegen einem rasanten Wandel (Davenport und Kirby, 2016). In Zeiten Künstlicher Intelligenz sollten nicht nur neue Funktionen oder Möglichkeiten der digitalen Tools beherrscht werden, auch das Nachvollziehen des Lernmusters der Maschinen sowie der Entscheidungen, die die Maschinen treffen, wird zur erforderlichen Kompetenz und Unternehmensaufgabe (Howard, 2019; Agrawal et al., 2023). Zukünftig wird der Umgang mit und das Verstehen von Künstlicher Intelligenz, die nun selbst „kognitive Aufgaben zu lösen hat“, zur Arbeitsaufgabe (Nassehi, 2021; S.233). Aktuelle Weiterentwicklungen der Technologien scheinen jedoch auch dieses Nachvollziehen der „Denk“- und „Lern“-Vorgänge der Künstlichen Intelligenz bald nahezu unmöglich zu machen. Und Veränderungen, die bis hin zu einer „Automatisierung von Entscheidungsroutinen“ (Ramge, 2020; S. 82f.) reichen können, lösen bei Beschäftigten unterschiedliche Beanspruchungen aus. Ängstlichkeit war in der zweiten Publikation das Gesundheitsoutcome, das nicht-lineare Zusammenhänge mit dem Tätigkeitsspielraum zeigte.

Hier ergibt sich weiterer Forschungsbedarf, denn es ist zu vermuten, dass es im Zusammenhang mit den Entwicklungen der Digitalisierung über die hier in der zweiten Publikation erhobenen „klassischen“ Angst hinaus auch Angst vor den „Maschinen“ an sich und beispielsweise ihrem Ersetzungspotential (Achim und Al Kassim, 2015; Pfaffinger et al., 2020) sein könnte, sowie vor allem die Angst vor falschen Entscheidungen, Fehlern oder das Nicht-Erfüllen von Erwartungen, die die Beschäftigten umtreibt (Bawden und Robinson, 2009; Lehner et al., 2013). Zukünftige Forschung sollte die Interdependenzen und Komplexität der digital vernetzten Arbeit berücksichtigen und somit den gesamten organisationalen Kontext in die Analysen der Auswirkungen miteinbeziehen (Cascio und Montealegre, 2016; Montealegre und Cascio, 2017; Dettmers und Bredehöft, 2020).

Es sind vor allem technologische Vorgaben, die sowohl zeitliche als auch inhaltliche Prozesse von Tätigkeiten bestimmen und dabei wenig bis keine Variationen erlauben. Die im Zuge der Subjektivierungsdebatte entstandene Anforderung der großen Spielräume öffnet das Spannungsfeld, in dem sich Beschäftigte verhalten und organisieren müssen (Niehaus, 2012; Mazmanian et al., 2013). Dem zu begegnen und eine gesunde Nutzung von Spielräumen zu ermöglichen, sollte kontinuierliche Aufgabe bei der Gestaltung von Arbeit sein (Dettmers und Clauß, 2018). Es braucht ein Match zwischen den Anforderungen der Arbeit und den Kenntnissen des Einzelnen. Hier wird deutlich, dass trotz des Einsatzes moderner Technologien die Bedeutung etablierter Theorien und Konzepte wie etwa dem Job-Demand-Control Modell erhalten bleibt.

Den Kriterien für eine menschengerechte Gestaltung von Arbeit folgend bedeutet dies, dass für die persönlichkeitsförderliche Gestaltung von Arbeit die kontinuierliche Weiterbildung der Beschäftigten gerade in der digitalisierten Arbeitswelt zentral sein kann (Rau, 2006; Van Ruysselveldt et al., 2011; Diebig et al., 2018; Tisch und Wischniewski, 2022).

So kann der Tätigkeitsspielraum auch weiterhin seine positive Wirkung entfalten.

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