Cognition, Technology & Work (2024) 26:139–152
https://doi.org/10.1007/s10111-023-00742-6

ORIGINAL ARTICLE

Sustainable employability, technology acceptance and task performance in workers collaborating with cobots: a pilot study

Eleonora Picco[1] · Massimo Miglioretti[1] · Pascale M. Le Blanc[2]

Received: 11 April 2023 / Accepted: 2 October 2023 / Published online: 18 October 2023

Abstract
Sustainable Employability (SE) and task performance of workers-collaborating-with-cobots is challenged. Whether SE policies can impact workers' task performance in digitalized workplaces is still unknown. Drawing on two SE models, this study aims to ascertain whether the relationship between SE policies and task performance is mediated by health and productive capabilities, and whether this effect is moderated by the levels of User Acceptance and Use of Technology (UTAUT) predictors. 88 employees collaborating with cobots, or expected to do so in the near future, answered a cross-sectional survey. SE policies were positively related to task performance via health and productive capabilities. This indirect effect was moderated by the levels of UTAUT predictors, being significant only at low or medium levels of the moderators. SE policies contribute to employee capabilities, and in turn to workers' task performance. Fostering health and productive capabilities is fundamental when employee levels of cobots' acceptance are not high yet.

Keywords Sustainable employability · Task performance · Capabilities · Technology acceptance · Collaborative robots

1 Introduction

The Industry 4.0 world of work is exponentially changed by digitalization and robotics (Alcover et al. 2021; Brougham and Haar 2017). Collaborative robots (cobots) are one of the key advanced technologies that can be used in a collaborative operation, where a specifically designed robot system and a human operator work in direct collaboration within a designated workspace (Mihelj et al. 2019). Differently from a cooperative interaction in which humans and robots work simultaneously towards a shared goal but have different interests, a collaborative interaction concerns a synergic work towards a common objective at the same time in the same workspace (Mathewson et al. 2022; Othman and Yang 2023). In contrast with traditional robotics, collaborative interactions require, therefore, close contact and high communication and coordination within the human-cobot system (Othman and Yang 2023). Instead of being replaced, human expertise, creativity, decision-making, flexibility and critical thinking can be integrated with the accuracy, repeatability and strength of cobots to optimize the performance of complex tasks (Othman and Yang 2023; Mathewson et al. 2022; Müller et al. 2016; Paliga 2023; Semeraro et al. 2023). While cobots can handle high-precision, hazardous or monotonous tasks, humans can take more innovative tasks (Othman and Yang 2023). As such, collaborative robotics has the potential to improve organizational performance, employee satisfaction and working conditions through human–machine interaction (Gualtieri et al. 2020; Paliga 2023).

However, some challenges and risks should be highlighted as well. Indeed, interaction between cobots and operators raises specific questions on how to ensure safety, ergonomics and security (Coupeté et al. 2016; Fraboni et al. 2023; Maurtua et al. 2017), how to avoid operators' health deterioration, cognitive workload or stress (Barcellini et al. 2023; Hopko et al. 2023; Longo 2018; Panchetti et al. 2023), and how to deal with employee anxiety, frustration and possible failure (Gualtieri et al. 2020; Paliga 2023; Panchetti

✉ Eleonora Picco
eleonora.picco@unimib.it

Massimo Miglioretti
massimo.miglioretti@unimib.it

Pascale M. Le Blanc
p.m.le.blanc@tue.nl

[1] Department of Psychology, University of Milano-Bicocca, Milan, Italy

[2] Department of Industrial Engineering and Innovation Sciences, Eindhoven University of Technology, Eindhoven, The Netherlands

et al. 2023), passion decay (Tang et al. 2022), or job insecurity (Yam et al. 2022). As the reciprocal roles played by workers are transformed by the collaboration with cobots (Alcover et al. 2021; Gualtieri et al. 2020) (e.g., workers can assume more responsibilities in supervising cobots and/or other operators, Goodrich and Schultz 2007; Schneider et al. 2022), both an organizational mindset modification supported by managers, and the adoption of a continuous learning approach are needed (Fraboni et al. 2023; Yuan and Woodman 2010). More specifically, highly advanced and technological skills and appropriate training of workers are fundamental to maintain human control over the machine (Gualtieri et al. 2020; Santoni de Sio and van den Hoven 2018; Tan et al. 2009). In some cases, the emergence of conflicts of autonomy or decisions between an operator and the system may even result in dangerous situations (Vanderhaegen 2021). Overall, due to the above-described possible risks, a participatory and inclusive human-centered approach (Kuru 2023; Vanderhaegen et al. 2021), focusing on workers' acceptance of cobots and preserving operators' sustainable employability is advocated (Fraboni et al. 2023; Lin and Lukodono 2021; Moniz 2013; van Zyl et al. 2023).

Sustainable Employability (SE) generally refers to workers' capabilities and willingness to continue working over the long-term (van der Klink et al. 2015). A worker who is sustainably employed is more likely to own an extensive set of capabilities, such as health capabilities, related to the preservation of his/her health, and productive capabilities, concerning the development of the right competencies to achieve work goals (Hazelzet et al. 2019). Due to its characteristics, human-cobot interaction is both an opportunity and threat to workers' SE (Smids et al. 2019). Indeed, as already stated, technology-rich environments are characterized by particular risk factors, such as high work pressure, loss of usual work routine, role ambiguity, and cognitive demands (Gualtieri et al. 2020) that can significantly put workers' health and productive capabilities at risk (Hazelzet et al. 2019; Picco et al. 2022a; van der Klink et al. 2015). As a consequence, operators' functioning, and task performance in particular, may be critically negatively affected (van der Klink et al. 2015). Furthermore, in these contemporary workplaces, workers' acceptance of cobots can be a crucial factor influencing successful human-cobot collaboration, and therefore operators' task performance (Bröhl et al. 2019).

1.1 Factors enabling successful human-cobot collaboration

Current literature has only started focusing on factors that enable satisfactory human-cobot interaction. For example, Paliga, following previous studies (Paliga 2022; Paliga and Pollak 2021), showed that fluency in human-cobot interaction (i.e., highly coordinated actions between cobot and human) is positively related both to job performance and satisfaction (2023). Further, quantitative workload moderated these relations: at its increase, the association between human-cobot interaction fluency and outcomes was decreasing (Paliga 2023). In an experimental study, Hopko et al. (2023) verified that cobots' unreliable manipulations, characterized by perturbations in cobots' movements, negatively impacted workers' trust in positive interaction with cobots, task efficiency and accuracy, and raised operators' stress levels. Reduced task efficiency was also associated with higher (cognitive) fatigue (Hopko et al. 2023). Similarly, in another experimental study, Vianello et al. (2023) found that changes in cobots' behaviors negatively impacted workers' movement performance. Moreover, these workers also preferred collaborative modes of interaction, in which the cobot maintains a steady role (2023). Finally, Panchetti et al. (2023) showed, through a series of experiments, that modifications in the workstation were associated with higher levels of cognitive performance and lower levels of cognitive workload among operators. Additionally, workers' acceptance of cobots predicted their stress, without impacting their cognitive workload.

Overall, the majority of existing studies has emphasized the role of quality and/or smoothness of tasks and actions synergically performed by the human-cobot system, in relation to effective system performance, whereas some studies have also considered the role of personal factors, such as cognitive workload or stress (Hopko et al. 2023). Up to our knowledge, up till now, no studies simultaneously investigated both the impact of contextual factors, such as organizational policies, and the role of factors operating at the interplay between the environment and the operator, such as technology acceptance, on the SE of workers that are collaborating with cobots and its related outcomes (e.g., task performance).

1.2 Study goal

The current study aims at addressing this gap in the literature by ascertaining whether the relationship between SE policies—i.e., organizational practices aimed at improving employee SE—and workers' task performance—as a fundamental indicator of SE—is mediated by health and productive capabilities, and whether this indirect effect is moderated by the (levels of) main predictors of workers' acceptance of cobots. As the Unified Theory of User Acceptance and Use of Technology (UTAUT), introduced by Venkatesh and Davis (2003), has already been applied to study human acceptance of collaboration with cobots, in this study we accordingly considered operators' acceptance of cobots as predicted by four main variables, called UTAUT main predictors (i.e., performance expectancy, effort expectancy, social influence and facilitating conditions) (Venkatesh and Davis 2003). This study was performed to answer to the following research question "What role do UTAUT main predictors have in activating workers' health and productive capabilities to achieve successful task performance in digitalized workplaces?".

2 Theoretical background

Van der Klink et al.'s model of SE (2015), and Picco et al.'s (2022a) additions to the model provide us with a framework to ascertain if, and, possibly, explain how SE policies impact employee task performance in digitalized workplaces. According to the model, and its subsequent specifications, SE outcomes, such as well-being and task performance, can be achieved at the workplace if: (1) personal and work factors are present (e.g., motivation and organizational policies, respectively), and (2) employee capabilities, such as health and productive capabilities, have been developed (Picco et al. 2022a; van der Klink et al. 2015). If these conditions are met, workers can choose if they want to achieve a specific SE outcome, such as task performance, by exploiting their capability set (van der Klink et al. 2015). In this choice of exploiting available capabilities, contextual factors are particularly important. Factors that predict workers' acceptance of cobots in digitalized workplaces—i.e., performance expectancy, effort expectancy, social influence and facilitating conditions (Venkatesh ansd Davis 2003)—may, therefore, influence employees' choice of exploiting their capabilities in the achievement of SE outcomes (van der Klink et al. 2015).

2.1 Sustainable employability policies and task performance

Due to specific risks such as mental workload (Gualtieri et al. 2020) that can significantly impact the success of human-cobot collaboration, a focus on those organizational policies that may contribute to operators' task performance is needed. In this study we consider organizational practices from a sustainable perspective by focusing on SE policies, which are organizational practices potentially improving employee SE, Ybema et al. 2017). In an attempt of mapping SE policies within an organization, the Netherlands Organization for Applied Scientific Research (TNO), provided a definition of these practices (2020). In particular, TNO underlined the importance of considering the degree of implementation and/or presence of: (1) a vision and strategy that embrace SE; (2) a structural approach for health promotion, career, knowledge and skills development, and attention to work-life balance; (3) resources allocated to working on health, development and work-life balance; (4) the integration of HRM practices in the scope of SE; (5) the extent to which employees are able to prepare plans and are informed about SE organizational strategies; and (6) a "learning organization" culture in which employees are respected and valued (TNO 2020). All these practices are driven by the strategic organizational goal of synergically contributing to employees' sustainable career over the long term (Ybema et al. 2017). In van der Klink et al.'s framework of SE (2015), organizational policies are assumed to increase the chance of sustainable employment, characterized by the achievement of, amongst others, an adequate work performance. Specifically, policies that aim at addressing employees' SE—defined as the set of employee capabilities, including health and productive capabilities (Picco et al. 2022a)—would potentially increase the task performance of employees collaborating with cobots.

Therefore, we argue that SE policies are positively related to operators' task performance, and we propose the following:

Hypothesis 1. SE policies are positively related with the task performance of workers collaborating with cobots.

2.2 Sustainable employability capabilities as mediators

Van der Klink et al. (2015) have based their model of SE on Amartya Sen's concept of capability (2015). This notion specifically refers to what a person can do, including personal resources and the interaction or fit with the context that allows the person to make use of his/her capabilities to attain sustainable outcomes (Fleuren et al. 2020; van der Klink et al. 2015). Starting from the model by van der Klink et al. (2015), Picco et al. (2022a) have conceptualized SE capabilities as divided in four core categories namely health, productive, valuable work, and long-term perspective capabilities. These categories include achievable opportunities related, respectively, to: (1) mental and physical health, or vitality, (2) productivity or safety behavior, (3) personal values, resources or job motivation, and (4) the exploitation of health, productive and valuable work opportunities over the long term. In this study we decided to focus only on health and productive capabilities, as discussed below. Health capabilities specifically concern employees' perception of achievability of aspects like taking care of their health while maintaining their job or dealing with work-related stress. For workers collaborating with cobots, these capabilities may be fundamental in allowing them to properly adapt to new safety challenges and to face mental and physical workloads (Huber et al. 2011; Gualtieri et al. 2020; Picco et al. 2022a). Productive capabilities particularly refer to employees' perception of attainability of aspects like having the right competencies and skills to perform the job, or the achievement of assigned work goals. Consequently, productive capabilities may be particularly relevant for operators collaborating with cobots due to the necessity of exercising and developing advanced collaborative and autonomy skills to perform the job effectively (Smids et al. 2019).

Importantly, according to van der Klink et al. (2015), capabilities would have a converting or mediating role in the achievement of valuable job outcomes. In this case, they would, thus, mediate the relationship between SE policies and task performance. We suggest that, in highly digitalized workplaces, SE policies could foster operators' health and productive capabilities that in turn would result in higher task performance. Therefore, we hypothesize the following:

Hypothesis 2. Health and productive SE capabilities mediate the relationship between SE policies and task performance of workers collaborating with cobots.

2.3 Technology acceptance main predictors as moderators

New technologies, including cobots, that enter our workplaces are generally successful only if employees really accept and want to work with them (Davis 1989; Venkatesh and Davis 2003). The Unified Theory of User Acceptance and Use of Technology (UTAUT, Venkatesh and Davis 2003) has argued that there are four core determinants of users' intention to use a specific technology (i.e., UTAUT main predictors), namely performance expectancy, effort expectancy, social influence and facilitating conditions. These dimensions respectively express: (1) the degree to which a person believes that using the technology will help her or him to achieve gains in job performance, (2) the degree of ease associated with the use of the technology, (3) the degree to which a person perceives that relevant others believe (s)he should use the new technology, and (4) the degree to which an individual believes that an organizational and technical infrastructure exists to support use of the system (Venkatesh and Davis 2003). In this sense, these main UTAUT predictors increase workers' intention to collaborate with a robot (Venkatesh and Davis 2003). Consequently, employees' levels of UTUAT predictors may moderate the hypothesized indirect relationship between SE policies and task performance. Or, in other words, the relevance of SE policies for operators' task performance via health and productive capabilities may be dependent on the levels of UTAUT main predictors.

In agreement with the discrepancy-arousal theory (Cappella and Greene 1982, 1984; Kluger and DeNisi 1998), we argue that SE policies are more strongly related to task performance among workers reporting low levels of UTAUT predictors, because it is among these workers that capabilities are more activated. According to this theory, an incongruity between what is provided or developed by the environment on the one hand, and what a person needs on the other hand, would stimulate him/her to initiate strategies to attain salient outcomes (Cappella and Greene 1982, 1984; Kluger and DeNisi 1998; Hochwarter et al. 2006). In particular, workers that report lower levels of performance expectancy, effort expectancy, social influence and facilitating conditions would be experiencing an incongruity between what the environment provides and what they need to collaborate effectively with cobots, and, therefore, these workers would be stimulated to initiate strategies to achieve adequate task performance (Cappella and Greene 1982, 1984; Kluger and DeNisi 1998; Hochwarter et al. 2006). It is in these "worse" conditions that workers would be triggered to activate their health and productive capabilities. Consequently, the UTAUT main predictors would moderate the indirect relationship between SE policies and task performance, by acting on the association between health and productive capabilities and task performance. In accordance with the above, we formulated the third hypothesis as follows:

Hypothesis 3. UTAUT main predictors moderate the indirect effect of SE policies on task performance via health and productive SE capabilities. This indirect effect would be stronger for workers that are collaborating with cobots and report low levels of UTAUT main predictors compared to workers collaborating with cobots that report high levels of UTAUT main predictors.

The hypotheses that guide this study are shown in Fig. 1.

3 Method

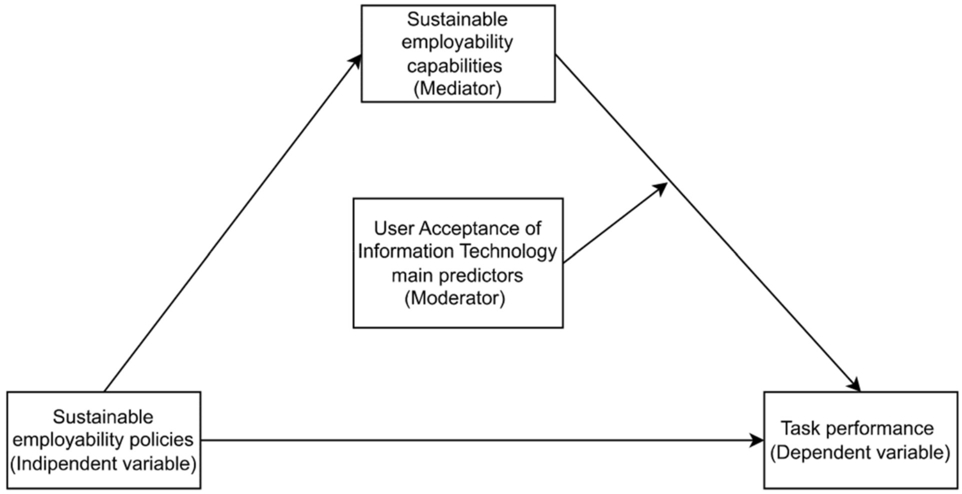
3.1 Design

Data to explore the impact of SE policies, UTAUT main predictors, and health and productive SE capabilities on workers collaborating with cobots' task performance, were collected through cross-sectional surveys. Two cross-sectional surveys were conducted in a company using collaborative robots in manufacturing processes (Manufacturing Sample, M Sample) and in a convenience sample recruited with the help of a company producing collaborative robots and offering trainings on how to maximize their utilization in businesses (Convenience Sample, C Sample).

3.2 Sample and procedure

Between January and March 2022, data were collected in a Northern Italy SME manufacturing eyewear and ski goggles that, at the time of the survey, had been using

Fig. 1 The proposed moderated mediation model



collaborative robots for 4 years for assembly and finishing tasks (i.e., molding injection, dispensing and laser marking). Forty two of the 80 employees involved in the M survey returned a pen and paper questionnaire, with a response rate of 49%. Thirty-nine questionnaires were finally included in the data analyses, after removing substantially incomplete questionnaires. Fourteen employees collaborated daily with robots, and the remaining 25 employees were expected to use them in a near future.

Between March and September 2022, additional data were collected by means of an online survey (C survey). Participants were recruited with the help of the Northern Italian site of a company producing, selling and offering training on how to use collaborative robots in various businesses. Participants were recruited through the company mailing list specifically targeting employees of companies that already adopted collaborative robots or had interest in doing that in the near future.

After removing incomplete questionnaires, 49 questionnaires were included in the data analyses. In order to obtain a bigger sample, data collected by means of both surveys were combined. Table 1 shows the descriptive statistics of the M sample, the C sample and the Total Sample (N = 88).

The following ethical measures were taken. Both studies were approved by the companies' General Managers. In the M study, participants were informed about the study in a corporate meeting, organized with the help of the HR Manager. In both studies, participants were free to refuse participation and welcomed to express concerns about the study. A completed questionnaire was taken to imply consent. The participants' privacy was guaranteed, and data were treated confidentially. Both studies were approved by the Ethics Committee of the University of Milano-Bicocca (RM-2022-500).

Table 1 Descriptive statistics of the total sample (N = 88)

Variable	Total sample M (SD)/%	M sample M (SD)/%	C sample M (SD)/%
Age (mean)	47.3 (11.5)	46.0 (9.1)	48.3 (13.0)
Gender (%)			
Men	64.8	28.2	93.9
Women	35.2	71.8	6.1
Educational level (%)			
Middle education	21.6	46.2	2.0
Secondary education	50.0	51.3	49.0
Post-secondary education or bachelor's degree	2.3	0.0	4.1
Master's degree	23.9	2.6	40.8
Post-degree master or PhD	2.3	0.0	4.1
Job role			
Manager	6.9	0.0	12.2
Supervisor	18.4	2.6	30.6
White-collar	18.4	0.0	32.7
Specialized blue-collar	4.6	0.0	8.2
Blue-collar	40.2	91.2	0.0
Trainee	2.3	0.0	4.1
Other	9.2	5.3	12.2
Type of contract			
Open-ended contract	3.4	97.4	95.8
Fixed-term contract	96.6	2.6	4.2
Use of collaborative robots			
Yes	35.2	35.9	34.7
In the near future	64.8	64.1	65.3

M Sample manufacturing sample, *C* sample convenience sample

3.3 Measures

Sustainable employability policies. Ten items from the Business Scan (TNO 2020) were adapted to measure employees' perception of availability of organizational sustainable employability policies regarding health and career promotion, allocation of resources, HRM practices, employee involvement and communication, and culture (e.g., "Your organization promotes healthy lifestyles and employee wellbeing"). Items were rated on a five-point scale from 1 (not at all) to 5 (very much), with higher scores indicating higher levels of sustainable employability policies (10 items, $\alpha = 0.95$).

Health capabilities Six items from the MAastricht Instrument for Sustainable Employability—Italian version (MAISE-IT, Picco et al. 2022b) were adapted to measure workers' perception of achievability of aspects such as taking care of health while maintain the job or dealing with work-related stress. The set begins with "In your current situation, how much do you feel the following aspects related to health to be achievable?", and an example item is "Work in a place where health and safety risks are managed". Items were rated on a five-point scale from 1 (not at all) to 5 (very much), with higher scores indicating higher levels of health capabilities (6 items, $\alpha = 0.92$).

Productive capabilities. Six items from the MAastricht Instrument for Sustainable Employability—Italian version (MAISE-IT, Picco et al. 2022b) were adapted to measure workers' perception of attainability of aspects like having the right competencies to perform the job or the achievement of assigned work goals. The set begins with "In your current situation, how much do you feel the following aspects related to competencies to be achievable?", and an example item is "Have the right competencies to perform my job". Items were rated on a five-point scale from 1 (not at all) to 5 (very much), with higher scores indicating higher levels of productive capabilities (6 items, $\alpha = 0.93$).

Performance expectancy. The "perceived usefulness" scale by Davis (1989) was used to measure the extent to which workers believe that using a cobot would improve their job performance (e.g., "Using a collaborative robot in my job would enable me to accomplish tasks more quickly"). The wording of the original items was tailored to "collaborative robot". Respondents answered six items on a scale ranging from 1 (strongly disagree) to 5 (strongly agree), with higher scores indicating higher levels of performance expectancy (6 items, $\alpha = 0.97$).

Effort expectancy. The "perceived ease of use" scale by Davis (1989) was used to measure the extent to which workers perceive that using a cobot would be free of effort (e.g., "Learning to operate with a collaborative robot would be easy for me"). The wording of the original items was tailored to "collaborative robot". Respondents answered six items on a scale ranging from 1 (strongly disagree) to 5 (strongly agree), with higher scores indicating lower levels of effort expectancy (6 items, $\alpha = 0.96$).

Social influence. The "social influence" scale by Apolinário-Hagen et al. (2018) was used to measure the degree to which workers perceive that significant others are of opinion (s)he should use a cobot (e.g., "People close to me would approve of a collaborative robot"). The wording of the original items was tailored to "collaborative robot". Respondents answered three items on a scale ranging from 1 (strongly disagree) to 5 (strongly agree), with higher scores indicating higher levels of social influence (3 items, $\alpha = 0.93$).

Facilitating conditions. The "facilitating conditions" scale by Apolinário-Hagen et al. (2018) was used to measure the degree to which workers believe that a technical and organizational infrastructure exist in their workplace to support the use of a cobot (e.g., "I have the necessary technical preconditions for using a collaborative robot"). The wording of the original items was tailored to "collaborative robot". Respondents answered two items on a scale ranging from 1 (strongly disagree) to 5 (strongly agree), with higher scores indicating higher levels of facilitating conditions (2 items, $\alpha = 0.91$).

Task performance. One item was used to measure workers' task performance, as defined by Borman and Motowidlo (1993), and developed by Shimazu et al. (2010). The item measures a worker's evaluation of his/her job performance in the last month, by considering the degree of achievement of his/her work goals: "Now rate your task performance over the past month on the basis of the achievement of what you consider to be your work goals". Respondents answered on a 11-point scale ranging from 0 (no work goal achieved) to 10 (all work goals achieved).

3.4 Demographics

The demographics collected by means of the surveys were age, gender, educational level, job role, type of contract and use of collaborative robots.

3.5 Data analyses

Descriptive and correlation analyses were first carried out using the SPSS 28 software package. Two regression analyses, predicting health and productive capabilities from the combination of control variables and SE policies were performed. Next, two mediation analyses, testing the mediation effects of health capabilities and productive capabilities, respectively, on the relationship between SE policies and task performance were conducted. This was followed by

Table 2 Means, standard deviations (SD) and correlations for the study variables (N ranges between 86 and 88)

Measure	Mean	SD	1	2	3	4	5	6	7	8	9	10	11
1. SE policies	3.05	0.92	1										
2. Health capabilities	3.51	0.80	0.56**	1									
3. Productive capabilities	3.73	0.87	0.52**	0.66**	1								
4. Performance expectancy	3.10	1.10	0.33**	0.14	0.08	1							
5. Effort expectancy	3.13	0.93	0.36**	0.26*	0.19*	0.58**	1						
6. Facilitating conditions	3.12	1.08	0.35**	0.31**	0.20*	0.44**	0.82**	1					
7. Social influence	3.03	1.03	0.44**	0.31**	0.21*	0.67**	0.55**	0.52**	1				
8. Task performance	7.46	1.76	0.33**	0.46**	0.42**	0.10	0.24*	0.23*	0.21*	1			
9. Age	47.3	11.5	– 0.04	– 0.03	0.01	– 0.16	0.03	– 0.09	– 20*	0.15	1		
10. Gender	–	–	–23*	– 0.27**	– 0.15	– 0.31**	– 0.53**	– 0.44**	– 0.31**	– 0.21*	– 19*	1	
11. Use experience of cobots	–	–	– 0.24*	– 0.23*	– 0.16	– 41**	– 0.23*	– 0.34**	– 0.44**	– 0.24*	0.16	0.15	1

**p < 0.001 * p < 0.05 (one-tailed)

performing moderated mediation analyses testing the moderation effects of UTAUT main predictors on the relationship between SE policies and task performance, mediated by health or productive capabilities, respectively. Process macro for SPSS was used for all mediation (model 4) and moderated mediation analyses (model 14) (Hayes 2018).

4 Results

Means, standard deviations and correlations of all study variables are presented in Table 2. The results showed that task performance was significantly positively correlated with SE policies, confirming Hypothesis 1. In this study, gender and use experience of cobots were significantly associated with task performance. Therefore, they were included as control variables in the following analyses testing Hypotheses 2 and 3. Age was not significantly associated with task performance. However, we decided to also include it to control for the possible influence of work experience on task performance (Ali and Davies 2003; Karanika-Murray et al. 2022; Saks and Waldman 1998).

Tables 3 and 4 show the results of the regression analyses. When health capabilities were regressed on SE policies and the control variables (Table 3), the relationship between SE policies and health capabilities was positive and statistically significant ($a = 0.49$, $p < 0.001$). When task performance was regressed on health capabilities, SE policies, and the control variables, the relationship between health capabilities and task performance was positive and statistically significant ($b = 0.45$, $p < 0.001$). Moreover, the direct effect of SE policies on task performance ($c = 0.05$) was not statistically significant.

When productive capabilities were regressed on SE policies and the control variables (Table 4), the relationship between SE policies and productive capabilities was positive

Table 3 Results of the regression analyses to test mediation of health capabilities (N = 80)

Dependent variable/predictors	B	SE	R^2
1. DV: Health capabilities			0.35**
Age	– 0.06	0.10	
Gender	0.15	0.10	
Use experience of cobots	0.13	0.10	
Sustainable employability policies	0.49**	0.10	
2. DV: Task performance			0.34**
Age	0.19	0.10	
Gender	0.08	0.10	
Use experience of cobots	0.14	0.10	
Sustainable employability policies	0.05	0.11	
Health capabiliities	0.45**	0.12	

SE Standard errors, *DV* dependent variable

**p < 0.001 (one-tailed)

Table 4 Results of the regression analyses to test mediation of productive capabilities (N = 80)

Dependent variable/predictors	B	SE	R^2
1. DV: Productive capabilities			0.27**
Age	– 0.01	0.10	
Gender	– 0.02	0.10	
Use experience of cobots	0.02	0.10	
Sustainable employability policies	0.52**	0.10	
2. DV: Task performance			0.32**
Age	0.17	0.10	
Gender	0.16	0.10	
Use experience of cobots	0.19	0.10	
Sustainable employability policies	0.07	0.11	
Productive capabiliities	0.39**	0.11	

SE Standard errors, *DV* dependent variable

**p < 0.001 (one-tailed)

and statistically significant ($a = 0.52$, $p < 0.001$). When task performance was regressed on productive capabilities, SE policies, and the control variables, the relationship between productive capabilities and task performance was positive and statistically significant ($b = 0.39$, $p < 0.001$). Moreover, the direct effect of SE policies on task performance ($c = 0.07$) was not statistically significant.

To test Hypothesis 2, proposing a positive indirect effect of the SE policies on task performance via health capabilities or via productive capabilities, the indirect effects *ab* and their 95% bootstrap confidence interval (CI) were computed with PROCESS (Model 4). We obtained the following results: indirect effect via health capabilities: B = 0.22, SE = 0.11; 95% CI [0.05, 0.49]; indirect effect via productive capabilities: B = 0.20, SE = 0.09; 95% CI [0.06, 0.41]. As these indirect effects were positive and the 95% confidence intervals did not contain zero, Hypothesis 2 was confirmed.

To test Hypothesis 3, proposing that the positive indirect effect of SE policies via health capabilities, and via productive capabilities, was moderated by the levels of UTAUT main predictors, we performed several moderated mediation analyses with PROCESS (Model 14). The indexes of moderated mediation testing the hypothesized conditional indirect effects via health capabilities were statistically significant while moderating for performance expectancy (B = − 0.18, SE = 0.07; 95% CI [− 0.32, − 0.04]), effort expectancy (B = − 0.14, SE = 0.07; 95% CI [− 0.27, − 0.00]), social influence (B = − 0.19, SE = 0.07; 95% CI [− 0.34, − 0.07]), and facilitating conditions (B = − 0.16, SE = 0.08; 95% CI [− 0.32, − 0.02]). The indexes of moderated mediation testing the hypothesized conditional indirect effects via productive capabilities were statistically significant while moderating for performance expectancy (B = − 0.16, SE = 0.08; 95% CI [− 0.32, − 0.02]), effort expectancy (B = − 0.14, SE = 0.06; 95% CI [− 0.27, − 0.02]), social influence (B = − 0.16, SE = 0.06; 95% CI [− 0.30, − 0.05]), and facilitating conditions (B = − 0.13, SE = 0.07; 95% CI [− 0.28, − 0.01]). These results indicate that the indirect effect of SE policies on task performance via health capabilities, and via productive capabilities, were dependent on the levels of UTAUT main predictors.

In particular, the indirect effects via health capabilities, and via productive capabilities were statistically significant at low levels of the moderators, but not at high levels. Indeed, when the moderators took the value of 1SD below its mean (− 1SD), the indirect effects via health capabilities were statistically significant (performance expectancy: B = 0.81, SE = 0.14; 95% CI [0.53, 1.10]; effort expectancy: B = 0.74, SE = 0.14; 95% CI [0.46, 1.02]; social influence: B = 0.79, SE = 0.13; 95% CI [0.53, 1.05]; facilitating conditions: B = 0.39, SE = 0.16; 95% CI [0.10, 0.72]). Coherently, when the moderators took the value of 1SD below its mean (-1SD), the indirect effects via productive capabilities were statistically significant (performance expectancy: B = 0.75, SE = 0.15; 95% CI [0.44, 1.05]; effort expectancy: B = 0.72, SE = 0.14; 95% CI [0.44, 1.00]; social influence: B = 0.69, SE = 0.13; 95% CI [0.43, 0.95]; facilitating conditions: B = 0.69, SE = 0.15; 95% CI [0.39, 0.99]). However, when the moderators took the value of 1SD above their mean (+ 1SD), the indirect effects via health capabilities (performance expectancy: B = 0.05, SE = 0.08; 95% CI [− 0.10, 0.24]; effort expectancy: B = 0.08, SE = 0.08; 95% CI [− 0.06, 0.26]; social influence: B = 0.01, SE = 0.09; 95% CI [− 0.16, 0.20]; facilitating conditions: B = 0.07, SE = 0.09; 95% CI [− 0.09, 0.26]), and via productive capabilities (performance expectancy: B = 0.08, SE = 0.08; 95% CI [− 0.04, 0.27]; effort expectancy: B = 0.10, SE = 0.07; 95% CI [− 0.02, 0.26]; social influence: B = 0.08, SE = 0.14; 95% CI [− 0.19, 0.36]; facilitating conditions: B = 0.10, SE = 0.08; 95% CI [− 0.04, 0.27]) were not statistically significant. Taking all these results together, Hypothesis 3 was supported. Figures 2 and 3 display the conditional indirect effects via health capabilities, and via productive capabilities, respectively, plotted for low and high levels of the moderators (i.e., performance expectancy, effort expectancy, social influence, and facilitating conditions).

5 Discussion

This study aimed to ascertain whether SE policies—defined as organizational practices that may improve employee SE (Ybema et al. 2017)—are directly and indirectly (through health and productive capabilities) related to workers' task performance, as a fundamental outcome of employee SE (Picco et al. 2022a; van der Klink et al. 2015). Furthermore, it was investigated whether this relationship was dependent on the levels of UTAUT main predictors (i.e., performance expectancy, effort expectancy, social influence and facilitating conditions). Data were collected among two independent samples of Italian workers collaborating with cobots or expected to do so in the near future. In line with the hypotheses, the results show that SE policies are related to the task performance of employees who are collaborating with cobots or are expected to do so in the near future. Moreover, we found that SE policies improve perceived health and productive capabilities at work. Among workers reporting low and medium levels of UTAUT main predictors, this, in turn, improved their task performance. That is, SE policies are significantly indirectly related to the task performance of employees who are collaborating with cobots through health and productive capabilities when they score low or medium on the UTAUT main predictors, but not if they score high on the UTAUT main predictors.

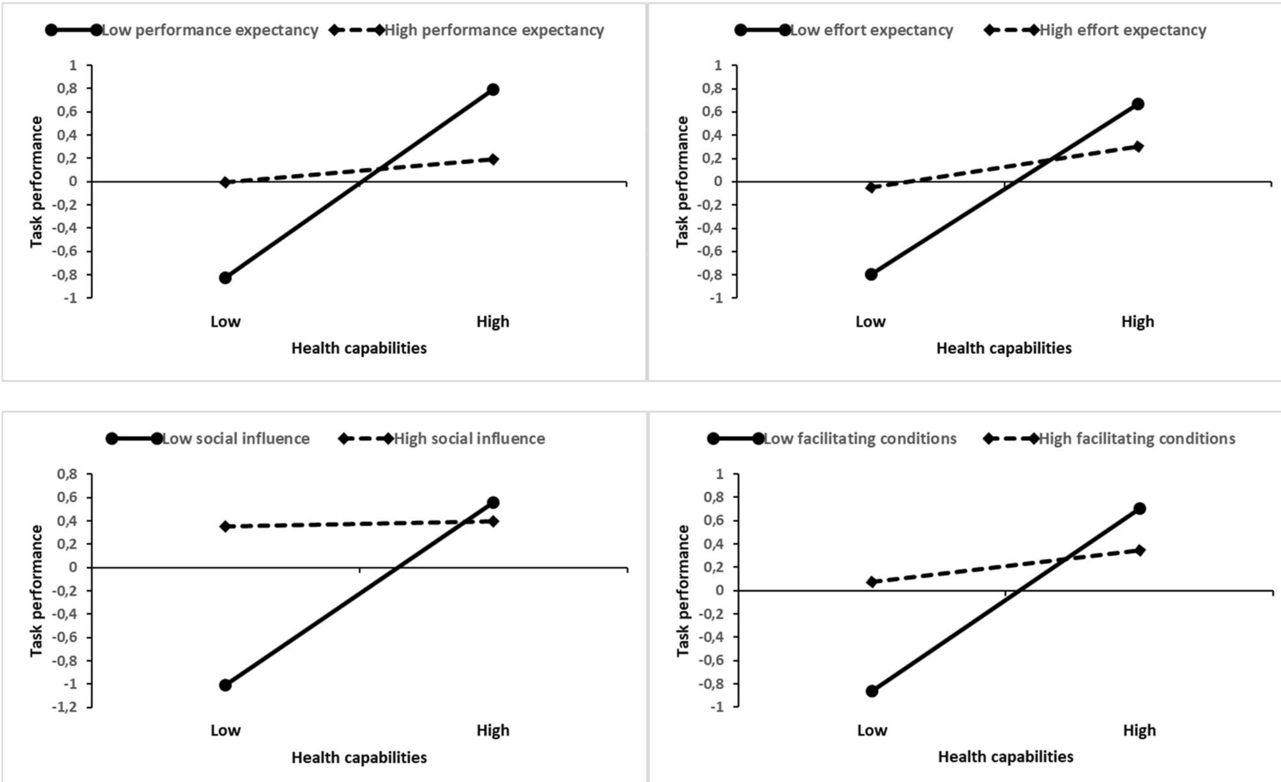


Fig. 2 Conditional indirect effects of UTAUT main predictors (i.e., performance expectancy, effort expectancy, social influence, and facilitating conditions) on task performance via health capabilities

5.1 Theoretical implications

This study, firstly, contributes to the model of SE as framed by van der Klink et al. (2015; Gürbüz et al. 2022), and integrated by Picco et al. (2022a), by coming up with empirical evidence on the key antecedent role of SE policies for the task performance of workers-collaborating-with-cobots. As previous research found task performance to be associated with SE (Abma et al. 2015; van Gorp et al. 2018), the antecedent role of SE policies in the prediction of employee task performance is a valuable finding in the framework of SE. This result is in line with Gürbüz et al. (2022), who showed that inclusive leadership behaviors and high-involvement practices, such as having role flexibility or sharing information at the workplace, fostered workers' SE. By considering the role of not only high-involvement HR practices but also of other organizational practices synergically addressing a vision and strategy that embraces SE (e.g., by allocation of resources for health, work-life balance and skills development, and a "learning organization" culture), this finding significantly enlarges our understanding of how digitalized organizations can foster employee task performance.

Secondly, the current study contributes to models of SE (Picco et al. 2022a; van der Klink et al. 2015) by providing empirical evidence for the associations between SE policies and health and productive capabilities, and between health and productive capabilities and task performance as a relevant SE outcome. In particular, this study constitutes the first attempt to empirically investigate the role of two categories of capabilities—health (i.e., addressing the maintenance of a good health) and productive (i.e., concerning the development of competencies to successfully perform) capabilities in high-tech workplaces. We showed that SE policies stimulate the development of health and productive capabilities of workers collaborating with cobots. On the other hand, as an extensive set of capabilities is considered as reflecting SE (Gürbüz et al. 2022; Picco et al. 2022a), the relationship between health and productive capabilities and task performance adds evidence for the association between SE and SE outcomes, as previously demonstrated by Abma et al. (2015), Gürbüz et al. (2022) and van Gorp et al. (2018). Overall, health and productive capabilities emerge as pivotal, both in connection with organizational factors (i.e., SE policies) and with operators' task performance.

Third, the present study made an original contribution to the literature by integrating the SE perspective with the UTAUT theory, with the aim of investigating the mechanisms of SE in digitalized workplaces like those where

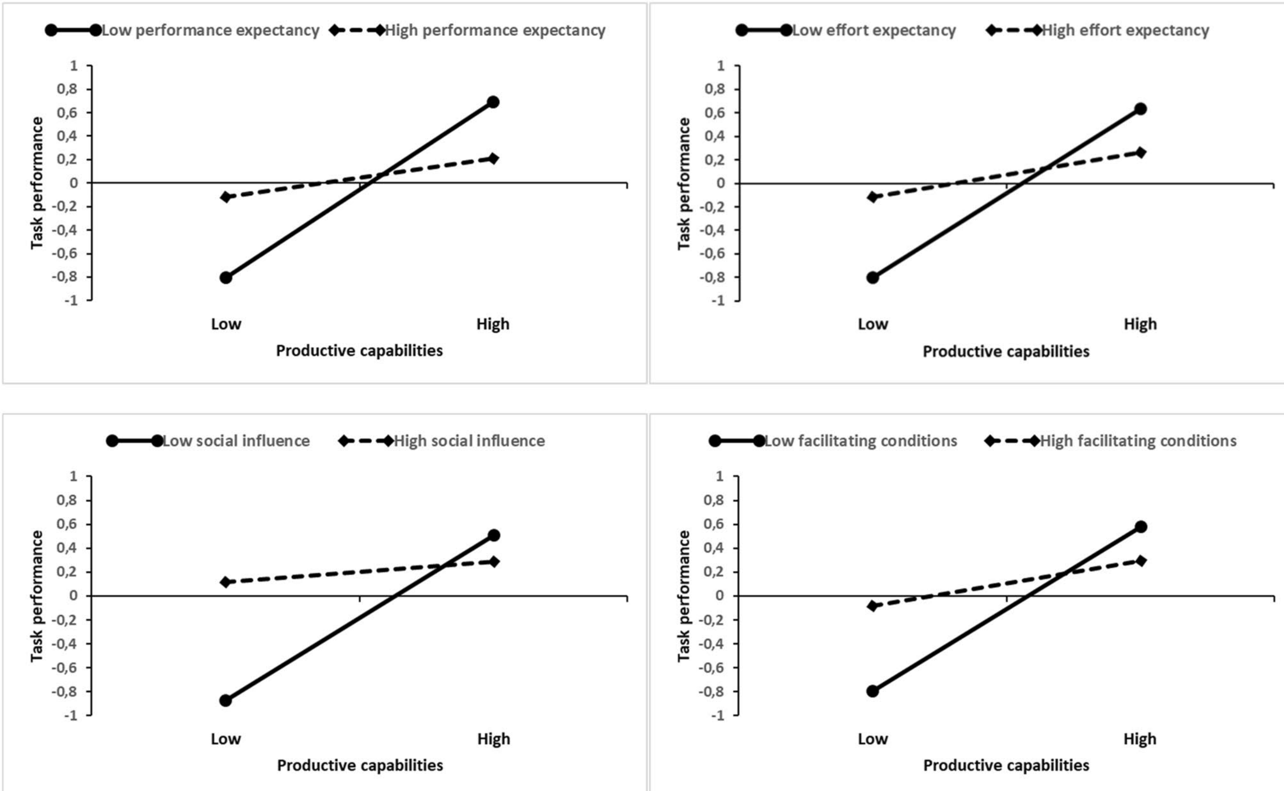


Fig. 3 Conditional indirect effects of UTAUT main predictors (i.e., performance expectancy, effort expectancy, social influence, and facilitating conditions) on task performance via productive capabilities

collaborative robots are adopted. By exploring the role of UTAUT main predictors in the context of the collaboration between workers and cobots, this study extends the field of technology acceptance, by providing an additional empirical test of the UTAUT model in work settings using collaborative robotics (Bröhl et al. 2019; Panchetti et al. 2023).

Interestingly, this study illuminated the mediating role of health and productive capabilities in the enhancement of the task performance of workers collaborating with cobots who report low or medium levels of UTAUT main predictors. This finding is in line with previous studies detecting similar phenomena of resources' exploitation (i.e., social skills and job crafting behaviors) when attaining salient outcomes (i.e., job performance and adaptive performance) in case of scarce environmental resources (i.e., organizational support and managers' influence tactics; Hochwarter et al. 2006; Vakola et al. 2022). This result is also, more broadly, in agreement with the discrepancy-arousal theory (Cappella and Greene 1982, 1984; Hochwarter et al. 2006; Kluger and DeNisi 1998) that argues that an incongruity between what is provided by the environment and what an individual needs would trigger the worker to initiate strategies to achieve relevant outcomes. The findings showed that the mediating role of health and productive capabilities is dependent on the levels of UTAUT main predictors, thus opening new conceptual questions in the study of SE in digitalized contexts.

Finally, in the light of SE models (Picco et al. 2022a; van der Klink et al. 2015), the findings of this study provide preliminary evidence for the role of workers' freedom and agency in realizing SE outcomes. Indeed, according to the findings, employees in digitalized workplaces would choose to use their capabilities to achieve higher levels of task performance only if their technology acceptance levels are critically low or medium.

5.2 Practical implications

Based on this study's results, several recommendations can be made for practitioners and firms aiming at promoting SE in digitalized workplaces. Firstly, the positive association between SE policies and task performance means that companies can enhance SE by developing these practices. Such policies should, therefore, implement a vision and strategy that embraces SE, allocating resources for health, work-life balance and skills development, integrating HRM practices in the scope of SE, and contribute to building a "learning organization" culture.

Second, this study revealed the mediating role of health and productive capabilities in the relationship between SE policies and employee task performance when conditions for acceptance of technology are low. Favoring the use of these capabilities functions as an essential footpath to foster employee task performance when acceptance of technology is not high yet, for example, at the beginning of the implementation process of cobots. In fact, in these conditions, in accordance with SE models (Picco et al. 2022a; van der Klink et al. 2015) and discrepancy-arousal theory (Cappella and Greene 1982, 1984; Kluger and DeNisi 1998), employees would be particularly triggered to use their capabilities to attain salient outcomes. SE policies aimed at developing workers' health and productive capabilities may, therefore, act as a fundamental step towards a successful human-cobot collaboration, especially in conditions of (still) low technology acceptance. When the levels of employee technology acceptance predictors are high, health and productive capabilities are not identified as being relevant for the achievement of an adequate task performance (no significant mediation effect). However, in the SE models based on the capability approach, capabilities are seen as the expression of a meaningful and personal contribution of each worker to his/her work (Picco et al. 2022a; van der Klink et al. 2015). Initiatives at the workplace aimed at, first, providing employees with adequate resources to accept cobots, and, secondly, empowering employees in the recognition of their valuable contribution to work would be particularly important in contexts where the implementation of cobots has just started. These actions would, possibly, increase the chances of keeping human–robot collaboration sustainable, and avoid mechanisms of reduced autonomy or simplification of work (Berkers et al. 2022).

Lastly, the current study is, up to our knowledge, the first one aimed at addressing SE of workers collaborating with cobots in Italian SMEs, advancing from a previous study advocating for the sensitization of Italian employers to SE promotion (Picco et al. 2022b). The Italian industry context is characterized by a high proportion of SMEs that are currently addressing the challenge of conversion into smart factories, by adopting and creating technical solutions for production, while developing sustainable management models (Matt et al. 2020; Osservatorio PMI Politecnico di Milano 2021). Despite of the fact that collaborative robots are particularly well suited for these businesses and the importance of acceptance issues is recognized, SMEs frequently lack comprehensive plans to spot obstacles and promote cobots' acceptance (Baumgartner et al. 2022). This study thus provides high priority insights to (Italian) employers about opportunities to increase the SE of their employees collaborating with cobots.

5.3 Limitations and future directions

Despite the evidence provided in this study on the moderated mediated association between SE policies and task performance of workers collaborating with cobots, some limitations should be highlighted. First, this study used cross-sectional data, formally not suited for the investigation of casual relationships. Future studies using experimental or longitudinal designs need to be conducted in order to understand the causal ordering of variables, capturing the time dimension of SE (Fleuren et al. 2020), and assessing the impact of cobots' usage over time. Second, our sample was relatively small and resulted from the combination of two independent samples. Only Italian workers, collaborating with a robot arm, mainly males, and partially belonging to the manufacturing industry were recruited. The generalizability of findings should, therefore, be taken with caution. In addition to improving the generalizability of the findings, a larger sample would have produced more trustworthy statistical results. However, it was difficult to recruit participants because employees and managers from the contacted manufacturing companies showed resistance to participate in this study as they felt this was interfering with their production processes. Future studies may try to replicate our results in larger samples of workers collaborating with cobots; in samples of workers with different seniority of collaboration with cobots; among employees using other kinds of collaborative robotics; in other industrial sectors; and in other countries where organizations are implementing and using cobots. Third, all measures were self-reported, raising questions about overestimation of effects and common method variance. Fourth, this study explored the association between SE policies, health and productive capabilities, and task performance at different levels of UTAUT main predictors among workers collaborating with cobots. Future research could consider different work (e.g., sustainable leadership) and individual (e.g., motivation) SE antecedents, various capabilities (e.g., valuable work capabilities), other SE outcomes (e.g., job satisfaction), and other variables that have been demonstrated relevant in the study of technology acceptance (e.g., attitude towards using cobots, or trust in cobots, Kim 2022; Maiolo and Zuffo 2018). Finally, more research on the relationships between technology acceptance and SE capabilities is recommended.

6 Conclusion

This study shows that health and productive capabilities play a mediating role in the relationship between SE policies and the task performance of employees collaborating with cobots, but only for those employees who report low or medium levels of UTAUT main predictors, and thus feel triggered to exploit their capabilities. Despite the small sample and cross-sectional design, this study provides insights into the mechanisms through which SE policies may contribute to a better task performance in digitalized workplaces. Overall, this research emphasizes the importance of adopting a sustainable approach to the fostering of employability and task performance among the contemporary workforce. This perspective synergically accounted for the complexity of bonds between personal, work and structural factors, by showing the weight of workers' agency and acceptance in the achievement of successful human-cobot collaboration. The relevance of human factors, besides technical requirements, for human-cobot interaction is, therefore, made very clear.

Author contributions EP designed the study, EP and MM collected data, EP performed the analyses, drafted the manuscript and designed the figures, MM, PMLB discussed the results, supervised the work and commented on the manuscript. All authors agreed on the final version of the manuscript.

Funding Open access funding provided by Università degli Studi di Milano - Bicocca within the CRUI-CARE Agreement. No funding was received for conducting this study.

Data availability The datasets generated during and/or analyzed during the current study are not publicly available due to the privacy of the participants, but are available from the corresponding author upon reasonable request.

Declarations

Conflict of interest The authors declare that they have no conflict of interest nor financial interests.

Ethical approval All subjects gave their informed consent for inclusion before they participated in the study. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of the University of Milano-Bicocca (RM-2022-500).

References

Abma FI, Brouwer S, de Vries HJ et al (2015) The capability set for work: development and validation of a new questionnaire. Scand J Work Environ Health 42:34–42. https://doi.org/10.5271/sjweh.3532

Alcover C-M, Mazzetti G, Vignoli M (2021) Sustainable employability in the mid and late career: an integrative review. Revista De Psicología Del Trabajo y De Las Organizaciones 37:157–174. https://doi.org/10.5093/jwop2021a16

Ali H, Davies DR (2003) The effects of age, sex and tenure on the job performance of rubber tappers. J Occup Organ Psychol 76:381–391. https://doi.org/10.1348/096317903769647238

Apolinário-Hagen J, Menzel M, Hennemann S, Salewski C (2018) Acceptance of mobile health apps for disease management among people with multiple sclerosis: web-based survey study. JMIR Format Res. https://doi.org/10.2196/11977

Barcellini F, Béarée R, Benchekroun T-H et al (2023) Promises of industry 4.0 under the magnifying glass of interdisciplinarity: revealing operators and managers work and challenging collaborative robot design. Cogn Technol Work 25:251–271. https://doi.org/10.1007/s10111-023-00726-6

Baumgartner M, Kopp T, Kinkel S (2022) Analysing factory workers' acceptance of collaborative robots: a web-based tool for company representatives. Electronics 11:145. https://doi.org/10.3390/electronics11010145

Berkers HA, Rispens S, Le Blanc PM (2022) The role of robotization in work design: a comparative case study among logistic warehouses. Int J Human Resour Manag. https://doi.org/10.1080/09585192.2022.2043925

Borman WC, Motowidlo SJ (1993) Expanding the criterion domain to include elements of contextual performance. In: Schmitt N, Borman WC (eds) Personnel selection in organizations. Jossey-Bass, San Francisco, pp 71–98

Bröhl C, Nelles J, Brandl C et al (2019) Human-robot collaboration acceptance model: development and comparison for Germany, Japan, China and The USA. Int J Soc Robot 11:709–726. https://doi.org/10.1007/s12369-019-00593-0

Brougham D, Haar J (2017) Smart technology, artificial Intelligence, robotics, and algorithms (stara): employees' perceptions of our future workplace. J Manag Organ 24:239–257. https://doi.org/10.1017/jmo.2016.55

Cappella JN, Green JO (1984) The effects of distance and individual differences in arousability on nonverbal involvement: a test of discrepancy-arousal theory. J Nonverbal Behav 8:259–286. https://doi.org/10.1007/bf00985983

Cappella JN, Greene JO (1982) A discrepancy-arousal explanation of mutual influence in expressive behavior for adult and infant-adult interaction1. Commun Monogr 49:89–114. https://doi.org/10.1080/03637758209376074

Coupeté E, Weistroffer V, Hugues O, et al (2016) New challenges for human-robot collaboration in an industrial context: acceptability and natural collaboration. In: Workshop "Towards a Framework for Joint Action (fifth edition)", IEEE RO-MAN 2016.

Davis FD (1989) Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Q 13:319. https://doi.org/10.2307/249008

Fleuren BP, de Grip A, Jansen NW et al (2020) Unshrouding the sphere from the clouds: towards a comprehensive conceptual framework for sustainable employability. Sustainability 12:6366. https://doi.org/10.3390/su12166366

Fraboni F, Brendel H, Pietrantoni L (2023) Evaluating organizational guidelines for enhancing psychological well-being, safety, and performance in technology integration. Sustainability 15:8113. https://doi.org/10.3390/su15108113

Goodrich MA, Schultz AC (2007) Human-robot interaction: a survey. Found Trends® Human-Comput Interact 1(3):203–275. https://doi.org/10.1561/9781601980939

Gualtieri L, Palomba I, Wehrle EJ, Vidoni R (2020) The opportunities and challenges of SME Manufacturing automation: safety and ergonomics in human–robot collaboration. In: Matt DT, Modrak V, Zsifkovits H (eds) Industry 4.0 for SMEs: challenges, opportunities and requirements. Palgrave Macmillan, London

Gürbüz S, Joosen MC, Kooij DT et al (2022) Measuring sustainable employability: psychometric properties of the capability set for work questionnaire. BMC Public Health. https://doi.org/10.1186/s12889-022-13609-8

Hayes F (2018) Introduction to mediation, moderation, and conditional process analysis: a regression-based approach, 2nd edn. The Guilford Press, New York

Hazelzet E, Picco E, Houkes I et al (2019) Effectiveness of interventions to promote sustainable employability: a systematic review. Int J Environ Res Public Health 16:1985. https://doi.org/10.3390/ijerph16111985

Hochwarter WA, Witt LA, Treadway DC, Ferris GR (2006) The interaction of social skill and organizational support on job performance. J Appl Psychol 91:482–489. https://doi.org/10.1037/0021-9010.91.2.482

Hopko SK, Mehta RK, Pagilla PR (2023) Physiological and perceptual consequences of trust in collaborative robots: an empirical investigation of human and robot factors. Appl Ergon 106:103863. https://doi.org/10.1016/j.apergo.2022.103863

Huber M, Knottnerus JA, Green L et al (2011) How should we define health? BMJ 343:d4163–d4163. https://doi.org/10.1136/bmj.d4163

Karanika-Murray M, Van Veldhoven M, Michaelides G et al (2022) Curvilinear relationships between age and job performance and the role of job complexity. Work Aging Retire. https://doi.org/10.1093/workar/waac006

Kim S (2022) Retail technology acceptance model for online at offline (O@O): comparing different generations of data analysis techniques. Int J Fash Des Technol Educ 15:394–406. https://doi.org/10.1080/17543266.2022.2078892

Kluger AN, DeNisi A (1998) Feedback interventions: toward the understanding of a double-edged sword. Curr Dir Psychol Sci 7:67–72. https://doi.org/10.1111/1467-8721.ep10772989

Kuru H (2023) Understanding employee wellness in industry 5.0: a systematic review. J Ekonomi 5:32–35. https://doi.org/10.58251/ekonomi.1266734

Lin CJ, Lukodono RP (2021) Sustainable human–robot collaboration based on human intention classification. Sustainability 13:5990. https://doi.org/10.3390/su13115990

Longo L (2018) Experienced mental workload, perception of usability, their interaction and impact on task performance. PLoS ONE 13(8):e0199661. https://doi.org/10.1371/journal.pone.0199661

Maiolo ME, Zuffo RG (2018) An evaluation of organizational trust: psychometric characteristics of the Italian version of workplace trust survey (I-WTS). TPM– Test Psychom Methodol Appl Psychol 25(2):273–304. https://doi.org/10.4473/TPM25.2.8

Mathewson KW, Parker AS, Sherstan C et al (2022) Communicative capital: a key resource for human-machine shared agency and collaborative capacity. Neural Comput Appl 35:16805–16819. https://doi.org/10.1007/s00521-022-07948-1

Matt DT, Modrák V, Zsifkovits H (eds) (2020) Industry 4.0 for SMEs: challenges, opportunities and requirements. Springer International Publishing, Cham. https://doi.org/10.1007/978-3-030-25425-4

Maurtua I, Ibarguren A, Kildal J et al (2017) Human–robot collaboration in industrial applications. Int J Adv Rob Syst 14:172988141771601. https://doi.org/10.1177/1729881417716010

Mihelj M et al (2019) Collaborative robots in robotics 2nd edition, vol 12. Springer, pp 173–187

Moniz A (2013) Robots and humans as co-workers? The human-centred perspective of work with autonomous systems. IET Working Papers Series 1–21. No: WPS03/2013. ISBN: 1646-8929

Müller R, Vette M, Mailahn O (2016) Process-oriented task assignment for assembly processes with human-robot interaction. Procedia CIRP 44:210–215. https://doi.org/10.1016/j.procir.2016.02.080

Netherlands Organisation for Applied Scientific Research (TNO) (2020) Business Scan. Unpublished confidential document. The Netherlands

Osservatorio PMI Politecnico di Milano (2021) Available from: https://www.osservatori.net/it/eventi/on-demand/convegni/convegno-risultati-ricerca-osservatorio-innovazione-digitale-pmi-convegno. Accessed 5 Jan 2023

Othman U, Yang E (2023) Human–robot collaborations in smart manufacturing environments: review and outlook. Sensors 23:5663. https://doi.org/10.3390/s23125663

Paliga M (2022) Human–cobot interaction fluency and cobot operators' job performance. The mediating role of work engagement: a survey. Robot Auton Syst 155:104191. https://doi.org/10.1016/j.robot.2022.104191

Paliga M (2023) The relationships of human-cobot interaction fluency with job performance and job satisfaction among Cobot operators—the moderating role of workload. Int J Environ Res Public Health 20:5111. https://doi.org/10.3390/ijerph20065111

Paliga M, Pollak A (2021) Development and validation of the fluency in human-robot interaction scale. A two-wave study on three perspectives of fluency. Int J Human-Comput Stud 155:102698. https://doi.org/10.1016/j.ijhcs.2021.102698

Panchetti T, Pietrantoni L, Puzzo G et al (2023) Assessing the relationship between cognitive workload, workstation design, user acceptance and trust in collaborative robots. Appl Sci 13:1720. https://doi.org/10.3390/app13031720

Picco E, Gragnano A, Daghini A, Miglioretti M (2022a) Systematic review of intervention studies to foster sustainable employability core components: implications for workplace promotion. Sustainability 14:3300. https://doi.org/10.3390/su14063300

Picco E, Houkes I, De Rijk A, Miglioretti M (2022b) The Maastricht instrument for sustainable employability – Italian version (MAISE-IT): a validation study. BMC Public Health. https://doi.org/10.1186/s12889-022-12872-z

Saks AM, Waldman DA (1998) The relationship between age and job performance evaluations for entry-level professionals. J Organ Behav 19:409–419. https://doi.org/10.1002/(sici)1099-1379(199807)19:4%3c409::aid-job842%3e3.0.co;2-6

Santoni de Sio F, van den Hoven J (2018) Meaningful human control over autonomous systems: a philosophical account. Front Robot AI. https://doi.org/10.3389/frobt.2018.00015

Schneider E, van Berkel N, Skov MB (2022) Hybrid Work for industrial workers: challenges and opportunities in using collaborative robots. In: Work of the Future, NordiCHI22.

Semeraro F, Griffiths A, Cangelosi A (2023) Human-robot collaboration and machine learning: a systematic review of recent research. Robot Comput-Integr Manuf 79:102432. https://doi.org/10.1016/j.rcim.2022.102432

Shimazu A, Schaufeli WB, Taris TW (2010) How does workaholism affect worker health and performance? The mediating role of coping. Int J Behav Med 17:154–160. https://doi.org/10.1007/s12529-010-9077-x

Smids J, Nyholm S, Berkers H (2019) Robots in the workplace: a threat to—or opportunity for—meaningful work? Philos Technol 33:503–522. https://doi.org/10.1007/s13347-019-00377-4

Tan JT, Duan F, Zhang Y, et al (2009) Human-robot collaboration in Cellular Manufacturing: Design and Development. 2009 IEEE/RSJ International Conference on Intelligent Robots and Systems. https://doi.org/10.1109/iros.2009.5354155

Tang PM, Koopman J, Elfenbein HA et al (2022) Using robots at work during the Covid-19 crisis evokes passion decay: evidence from field and experimental studies. Appl Psychol 71:881–911. https://doi.org/10.1111/apps.12386

Vakola M, Xanthopoulou D, Demerouti E (2022) Daily job crafting and adaptive performance during organizational change: the moderating role of managers' influence tactics. J Appl Behav Sci. https://doi.org/10.1177/00218863221133622

van der Klink JJL, Bültmann U, Burdorf A et al (2015) Sustainable employability – definition, conceptualization, and implications: a perspective based on the capability approach. Scand J Work Environ Health 42:71–79. https://doi.org/10.5271/sjweh.3531

van Gorp DA, van der Klink JJ, Abma FI et al (2018) The capability set for work – correlates of sustainable employability in workers with multiple sclerosis. Health Qual Life Outcomes. https://doi.org/10.1186/s12955-018-0942-7

van Zyl LE, Dik BJ, Donaldson SI et al (2023) Positive organisational psychology 2.0: embracing the technological revolution. J Posit Psychol. https://doi.org/10.1080/17439760.2023.2257640

Vanderhaegen F (2021) Heuristic-based method for conflict discovery of shared control between humans and autonomous systems - a driving automation case study. Robot Auton Syst 146:103867. https://doi.org/10.1016/j.robot.2021.103867

Vanderhaegen F, Nelson J, Wolff M, Mollard R (2021) From human-systems integration to human-systems inclusion for use-centred inclusive manufacturing control systems. IFAC-PapersOnLine 54:249–254. https://doi.org/10.1016/j.ifacol.2021.08.029

Venkatesh M, Davis D (2003) User acceptance of information technology: toward a unified view. MIS Q 27:425. https://doi.org/10.2307/30036540

Vianello L, Ivaldi S, Aubry A, Peternel L (2023) The effects of role transitions and adaptation in human–cobot collaboration. J Intell Manuf. https://doi.org/10.1007/s10845-023-02104-5

Yam KC, Tang PM, Jackson JC et al (2022) The rise of robots increases job insecurity and maladaptive workplace behaviors: multimethod evidence. J Appl Psychol. https://doi.org/10.1037/apl0001045

Ybema JF, van Vuuren T, van Dam K (2017) HR practices for enhancing sustainable employability: implementation, use, and outcomes. Int J Human Resour Manag 31:886–907. https://doi.org/10.1080/09585192.2017.1387865

Yuan F, Woodman RW (2010) Innovative behavior in the workplace: the role of performance and image outcome expectations. Acad Manag J 53:323–342. https://doi.org/10.5465/amj.2010.49388995