Am I still human? Wearing an exoskeleton impacts self-perceptions of warmth, competence, attractiveness, and machine-likeness

Sandra Maria Siedl & Martina Mara
Robopsychology Lab, Johannes Kepler University Linz
Altenberger Straße 69, 4040 Linz, Austria

Am I still human? Wearing an exoskeleton impacts self-perceptions of warmth, competence, attractiveness, and machine-likeness

Abstract

Occupational exoskeletons are body-worn technologies capable of enhancing a wearer's naturally given strength at work. Despite increasing interest in their physical effects, their implications for user self-perception have been largely overlooked. Addressing common concerns about body-enhancing technologies, our study explored how real-world use of a robotic exoskeleton affects a wearer's mechanistic dehumanization and perceived attractiveness of the self. In a within-subjects laboratory experiment, n = 119 participants performed various practical work tasks (carrying, screwing, riveting) with and without the *Ironhand* active hand exoskeleton. After each condition, they completed a questionnaire. We expected that in the exoskeleton condition self-perceptions of warmth and attractiveness would be less pronounced and self-perceptions of being competent and machine-like would be more pronounced. Study data supported these hypotheses and showed perceived competence, machine-likeness, and attractiveness to be relevant to technology acceptance. Our findings provide the first evidence that body-enhancement technologies may be associated with tendencies towards self-dehumanization, and underline the multifaceted role of exoskeleton-induced competence gain. By examining user self-perceptions that relate to mechanistic dehumanization and aesthetic appeal, our research highlights the need to better understand psychological impacts of exoskeletons on human wearers.

Keywords

Exoskeleton, self-perception, dehumanization, attractiveness, technology acceptance, workplace

1. Introduction

From augmented reality glasses and smartwatches to smart clothing and bionic prosthetics, wearable devices of increasing sophistication can be found in all areas of everyday life. Over the past two decades, exoskeletons – body-worn robots that provide external physical assistance to their human wearers – have gained increasing attention across diverse fields of application: from healthcare and assisted living to the military and the workplace (Bogue, 2018; K. G. Davis et al., 2020; Gorgey, 2018; Proud et al., 2022). In contrast to implanted technologies (Lu et al., 2020; Olarte-Pascual et al., 2021), most exoskeletons are worn overtly and are therefore easily recognized as exogenous, technical elements. The physical presence of an exoskeleton may be noticeable not only visually, but also because of its operating noise (Groos et al., 2020; Shore et al., 2020), including sounds generated by the activation of servomotors (Moore et al., 2017). Depending on their size, design and, functionality, various systems are capable of altering the appearance of their users and thus elicit perceptions in ways reminiscent of a fusion of human and machine (Siedl & Mara, 2022): For example, workers who used exoskeletons reported feeling and looking like "Robocop" or were called "cyborg" by their colleagues. This concept of the cyborg, a portmanteau of cybernetic and organism, evoked in observers and users is typically characterized by its hybridity, blending the organic (human) with the artificial-technical (non-human) (Haraway, 1991). Being a cyborg also implies the idea of a technologically driven augmentation of human capabilities to overcome existing, natural restrictions (Pelegrín-Borondo et al., 2017). In robotic exoskeletons for occupational use[1], the notion of human enhancement may be triggered by their very purpose – to actively amplify physical strength and endurance of non-disabled, healthy workers (Raisamo et al., 2019). Although robotic exoskeletons for industry are often promoted to reduce physical demands and the risk of

[1] Note. The current literature refers to exoskeletons intended for workplace application as *industrial* or *occupational* exoskeletons.

work-related musculoskeletal stress (Huysamen et al., 2018; Kuber & Rashedi, 2021; Steinhilber et al., 2020), they are also discussed as tools for increasing productive performance (Bogue, 2018; Gilotta et al., 2019; Lowe et al., 2019) and thus fuel debates about a possible "technological dehumanization" (Montague & Matson, 1983) of workers (Agarwal & Deshpande, 2019; Greenbaum, 2016; Montague & Matson, 1983). In a mechanistic sense, dehumanization is associated with seeing a person as less warm, more machine-like, and often also as more competent (Fiske, 2009; Haslam, 2006; Haslam et al., 2004).

Early studies exploring views on new transplant technologies have suggested that the concept of integrating mechanical devices into the human body could trigger the fear of creating a mechanized self (Lai, 2012). With respect to exoskeleton technology, comparable concerns address, for example, dehumanization effects in the care relationship (Del Rio Carral et al., 2022; Veruggio et al., 2016) or in the workplace in retail and service settings (Tarbit et al., 2023). Given this fear of dehumanization associated with the use of exoskeletons, the question arises to what extent exoskeleton technology can actually bring about changes in perceived human characteristics and competencies. From field studies in food retail, we know that an anticipated roll-out of exoskeletons at the workplace already makes people think about what they would look like wearing an exoskeleton and what characteristics they would attribute to themselves. (Siedl & Mara, 2022). Positive self-perceptions (e.g., perception of competence) serve as an important source for personal well-being (Wojciszke, 2005) and may also be relevant to technology adoption (Siedl & Mara, 2021; Upasani et al., 2019). However, previous empirical studies evaluating exoskeletons have hitherto neglected dehumanized self-perception. Additionally, the body of research involving real-world use of exoskeletons remains limited in both scope and depth.

We thus sought to illuminate on the basis of real-life exoskeleton use the potential of robotic exoskeletons to influence self-perception associated with mechanistic dehumanization. To this end, we conducted a within-subjects laboratory experiment with the

Ironhand active hand exoskeleton in a simulated work setting. Investigating the direct experience of participants, we assessed how warm, competent, and machine-like they felt with versus without the exoskeleton. We further examined changes in perceived attractiveness and took a closer look at how these findings interrelate with a person's willingness to continue technology use.

2. Theoretical Background and Related Work

The ASTM International Technical Committee on Exoskeletons and Exosuits (ASTM F48) specifies industrial exoskeletons as wearable devices capable of augmenting, enabling, assisting or enhancing motion, posture, or physical activity (Lowe et al., 2019, 230f). This is in contrast to medical (rehabilitation) purposes, where exoskeletons as orthoses restore humans' physical capabilities or compensate for physical limitations (Pons et al., 2008). Exoskeletons which employ unpowered but load-bearing components, such as springs, are considered to be "passive" and primarily intended to relieve the user (Bär et al., 2021; Siedl et al., 2021)."Active" devices, also known as robotic exoskeletons, typically integrate at least one external actuator, such as an electrical power source, and seek to provide additional energy to the user (Toxiri et al., 2018). The majority of occupational exoskeletons focus on assisting the back or providing arm/shoulder support, but a handful of devices are also designed to support other body functions, for example, the grip force of the hand (Mayer et al., 2022). Independently of their functionality, exoskeletons are described as either rigid or soft (Lowe et al., 2019; Thalman & Artemiadis, 2020). Whereas rigid devices integrate stiff structures, such as solid plastic or steel, soft systems are characterized by their elastic fabric and tendon-based mechanisms, which allow a less complex, lightweight design (Babič et al., 2021; Bützer et al., 2021)

Whether rigid or soft, exoskeletons as body-worn enhancing systems are among the most highly visible wearables compared, for example, to smart glasses or smart implants (Grewal et al., 2020). Alongside system design, exoskeleton usage has been shown to trigger thoughts about personal appearance (i.e., what users look like) (Cha et al., 2020; Siedl & Mara, 2022; Upasani et al., 2019). Previous qualitative research has indicated that wearing an exoskeleton may give the impression of needing assistance (Baltrusch et al., 2020), implicitly suggesting that a person has physical problems or deficits that need to be compensated for. However, use of high-tech wearable systems could also make users appear more competent if these artificial systems are assumed to improve human functionality (Grewal et al., 2020; Mandl et al., 2022). Social cognitive theories of mental representations specifically link perceived competence to ability-related traits, such as being skillful or effective (Fiske et al., 2007). As research from the field of prosthetics has indicated, able-bodied wearers of highly sophisticated technical devices might also be seen as colder (Meyer & Asbrock, 2018), which reflects the perception of warmth that is associated with traits such as perceived friendliness and sincerity (Fiske et al., 2007). In an online experiment, Meyer and Asbrock (2018) found users of bionic prostheses with physical disabilities to be perceived as more competent, but not as colder than physically disabled persons without bionic assistance. In contrast, technically enhanced humans ("cyborgs") were perceived as colder and more competent than able-bodied individuals without technical enhancements. Overall, the use of devices to augment healthy, non-impaired persons –the primary target group for occupational exoskeletons – thus seems to be evaluated more negatively.

Within the Stereotype Content Model (SCM) (Fiske et al., 2002), the dimensions of warmth and competence serve as indicators of attributed good (warm) versus bad (cold) intentions (degree of warmth) and of the ascribed capability of enacting these intentions (degree of competence, ranging from incompetent to competent). Attributions of perceived warmth and competence ascribed to individuals or social groups are meant to predict stereotypes that in turn lead to emotional prejudices and ultimately influence people's behavior (discriminatory vs. supportive) (Cuddy et al., 2007). With reference to the discussion of alienating effects of modern technology (Haslam, 2006; Haslam et al., 2008; Montague &

Matson, 1983), lower levels of warmth and higher levels of competence within the SCM may prompt dehumanization in its mechanistic form (Haslam et al., 2008). Mechanistic dehumanization involves divesting people of fundamental person characteristics that are part of human nature and emphasize their personhood (Haslam, 2006; Haslam et al., 2004). Thus, human beings are reduced to objects or automata, typically represented by machines, robots, or mere instruments (Baldissarri, Valtorta, et al., 2017; Fiske, 2009; Haslam et al., 2007). Since a denial of human nature has been suggested to be accompanied with both a lack of warmth and seeing others as inert and rigid (Haslam, 2006), technomorphism must be mentioned as a related construct. Reciprocal to anthropomorphism (i.e., the tendency to ascribe human characteristics to non-human agents) (Aggarwal & McGill, 2007; Epley et al., 2007), technomorphism involves the attribution of machine-like traits to humans (Lum, 2021; Lum et al., 2014; Lum et al., 2012). Within the present research context, this signifies that a person wearing an exoskeleton is prone to being perceived as more unnatural, rigid in movement, and externally controlled (as one would assume for a robot) (Bartneck et al., 2009).

Previous research into dehumanization has revealed that a denial of humanness encompasses not only severe and absolute manifestations often observed in conditions of conflict, but also more nuanced and everyday forms arising from comparative evaluation (i.e., ascription of less humanness relative to others or compared to other times) (Bastian & Haslam, 2010; Haslam, 2006). Mechanistic dehumanization can occur in interpersonal interactions and intergroup dynamics, and is also likely to be observed in organizational settings (Christoff, 2014; Haslam & Bain, 2007; Haslam et al., 2005). With respect to the workplace, previous research empirically explored the objectification of employees (i.e., the perception of workers as objects or instruments) and its mechanisms and effects. Gruenfeld et al. (2008) found workplace objectification to arise in hierarchical work setups, where employees in high-power positions tended to emphasize the instrumental utility of their subordinate workers while disregarding their human qualities. In three experimental studies, Andrighetto et al. (2017) investigated the consequences of physical work activities – those that are highly repetitive, fragmented, and machine-dependent (Blauner, 1964) – on industrial workers to ascertain whether they promote objectification. They found that workers were perceived more as instruments and with a reduced ability to experience human mental states, particularly when participants focused on the manual labor rather than on the industrial worker as a person. These findings indicate that specific characteristics of industrial work can contribute to a dehumanized view of workers by others. Analyzing the psychological consequences of work objectification in hierarchical work relationships, Baldissarri et al. (2014) reported that subordinate workers who perceived themselves as being treated as mere tools by their superiors tended to internalize this view and objectify themselves. More precisely, a worker's perception of being objectified by their superior was positively linked to a rise in emotional exhaustion. In line with the literature on job burnout (cf. Maslach et al., 2001), higher levels of emotional exhaustion were associated with an increase in cynicism among workers, which was in turn closely related to a reduced tendency to attribute various human mental states to themselves (referred to as self-objectification). In addition to objectification triggered by others, the nature of work itself was found to trigger self-dehumanization by enhancing workers' self-perceptions of being object-like (Baldissarri, Andrighetto, et al., 2017). Building on these insights, a study by Valtorta and Monaci (2023) involving 142 Italian supermarket workers also confirmed the self-objectifying effect of work on staff members executing low-status job activities. Further, the perceived self-objectification of participating retail workers had a negative effect on their affective commitment to the organization. Bastian and Haslam (2010) investigated perceptions of self-dehumanization in a study on social ostracism. They revealed that participants who faced social exclusion considered themselves to be less human and warm, and colder and more mechanical. Experiencing mechanistic dehumanization was further found to predict cognitive deconstructive states (e.g., missing clear and meaningful thought, numbing) and evoke feelings of sadness and anger (Bastian & Haslam, 2011).

3. The Current Research

As described above, there are many reasons why people deny their own human qualities and dehumanize themselves at work. Research into dehumanization has revealed the detrimental effects of various kinds of dehumanizing perceptions on people's well-being (with respect to the organizational context, also see Bell & Khoury, 2011, 2016; Caesens et al., 2017). Conversely, positive self-perceptions represent a significant resource within the workplace, as we know, for example, from the literature on self-efficacy beliefs (cf. Barbaranelli et al., 2018; Beas & Salanova, 2006; Ma et al., 2021), which addresses a person's confidence in their ability to successfully perform a specific task or accomplish a desired goal (Bandura, 1977, 1986). Although fragmented factory work and social dynamics have previously been identified to trigger the emergence of self-dehumanization in the workplace (Baldissarri, Andrighetto, et al., 2017; Baldissarri et al., 2014), little is currently known about the direct impact of modern wearable technology on this phenomenon. Thus, it remains unclear how robotic exoskeletons – a technology that is tightly coupled to the human body – may shift users' self-perceptions towards more mechanically dehumanized selves in the workplace.

In their work on the Stereotype Content Model, Cuddy et al. (2008) noted that the dimensions of warmth and competence, traditionally used to judge other people, might also be relevant to self-evaluation. Building on Haslam's conceptualization of mechanistic dehumanization (Haslam, 2006), we therefore propose the following hypotheses with respect to active exoskeletons:

H1. *Wearing an exoskeleton decreases self-perceived warmth.*

H2. *Wearing an exoskeleton increases self-perceived competence.*

Exoskeletons with their various technical components and their supporting and fixing mechanisms alter the physical appearance of their wearers. The visual dimension of system design, however, is only part of the story (Blanchy et al., 2015): In addition to structural properties, such as color and form, system design also encompasses, for example, auditive and tactile responses, and strongly focuses on a user's experience while interacting with a system. In the context of exoskeletons, this might include system inertia (fluidity of movement) or how users can exert control over the device as well as over their bodies (Maurice et al., 2018). Since people who face mechanistic dehumanization are typically ascribed increasing similarity with machines or robots, we assume that exoskeleton usage changes a wearer's perception in terms of more self-attributed machine-likeness. Consequently, we propose:

H3. *Wearing an exoskeleton increases self-perceived machine-likeness.*

That exoskeletons are clearly visible when worn additionally raised questions regarding their aesthetic quality, which has also turned out to be pertinent to a user's willingness to initially use exoskeletons (Siedl & Mara, 2022). Further, the perceived physical attractiveness was found to be linked to positive self-image (Patzer, 1997). With respect to robotic exoskeletons, the present study therefore sought to understand how their use affects self-attributed attractiveness of those who wear them.

H4. *Wearing an exoskeleton decreases self-perceived attractiveness.*

If users feel more like machines when wearing occupational exoskeletons, one might expect them to reject a system. Research into technology acceptance has revealed that self-perceptions, such as technology self-efficacy and individual system use-related anxiety may play an indirect role in predicting intention to use (Venkatesh & Bala, 2008). In the context of smartwatches as wearable devices, visibility turned out to be an additional key factor for intention to use, as did attributing some kind of fashion status to the technology (Chuah et al., 2016; Ferreira et al., 2021). In order to increase our understanding of the influence of positive and negative self-perceptions on exoskeleton acceptance, we strove to explore whether a user's intention to use an exoskeleton is linked to self-perceptions of warmth, competence, machine-likeness, and attractiveness by proposing the following hypothesis.

H5. *Self-perceptions of warmth, competence, machine-likeness, and attractiveness are associated with a person's intention to use an exoskeleton.*

4. Methods

4.1. Study Design

This study manipulated exoskeleton usage in a laboratory experiment and employed a within-subjects design. Participants were placed under two conditions, one *with* and one *without* using a commercial active hand exoskeleton while executing predefined tasks at three task stations. The order of conditions was randomized to prevent systematic influences by learning or fatigue effects. Therefore, half of the participants started by using the exoskeleton before performing the same tasks without the device. The other half of the participants initially performed the tasks without exoskeleton support and used the device in the second run. After each condition, participants were asked to complete a questionnaire. The evaluation included self-perceptions of warmth, competence, and machine-likeness as dependent variables. It took participants about 55 minutes to complete the experiment, which was conducted in a closed space at the *LIT Open Innovation Center* at Johannes Kepler University Linz in October 2021.

4.2. Participants and Sample-Size Justification

We conducted an a priori power analysis with G*Power (Faul et al., 2007) for a non-parametric comparison of matched pairs. For the calculation, we assumed a medium effect size of $f = .25$, set α error probability to .05, and targeted a power $(1 - \beta)$ of 80 %, which is the probability to find an effect provided that there is a true effect. The power analysis set a target minimum sample size of 106 participants.

In total, 122 German-speaking people took part in the experiment. They were recruited either via a social media announcement on site on the university campus or via snowball sampling (Vogt & Johnson, 2011); that is, previous participants helped in finding new participants. None of them received payment. Data from two participants had to be excluded, as they had answered the attention check items incorrectly. One additional participant was screened out because she reported poor German speaking skills. The remaining n = 119 participants formed the final sample (37.82 % women; 61.34 % men; 0.84 % non-binary) and were aged from 18 to 62 years (M_{age} = 28.55, SD_{age} = 9.25). Of these, 91.60 % indicated no prior personal experience with any kind of exoskeleton, while seven participants had tried another exoskeleton once, and three more than once. Since the hand exoskeleton was applied to the right hand, we also checked for handedness (86.55 % right-handed, 11.76 % left-handed, 1.68 % ambidextrous), which had no effect on our variables of interest.

4.3.Procedure

The laboratory experiment consisted of an introductory phase, execution and evaluation phases, and the debriefing of participants (see *Figure 2*). The pretext used was that the active hand exoskeleton was undergoing tests in tasks representative of everyday work in a local carpentry company collaborating with the university. We explained that the study was composed of two tests – one completing the tasks with and one without wearing the exoskeleton – and required filling out a questionnaire after each test run. We thoroughly explained the purpose and functionality of the exoskeleton to the participants and informed them comprehensively about the risks of the study. We explicitly emphasized that participation was voluntary and could therefore be terminated at any time during the experiment. All participants gave written informed consent and agreed on data collection and photo documentation.

After sanitizing their hands, we equipped participants with protective gear. They put on a protective work coat, protective caps for their shoes, and safety glasses. To protect their hands, they were given work gloves. Although we selected non-hazardous work tasks (e.g., no use of hammers or drills involved), the protective equipment was intended to minimize the residual risk of potential injury. Participants who were to use it in the first run received assistance in putting on the exoskeleton. They then practiced proper handling of the exoskeleton by lifting and grasping a wooden plate and by using a ratchet screwdriver to turn a screw into a piece of wood. The tasks to be performed were explained and demonstrated directly at the corresponding stations. Since the exoskeleton required right-handed use, involvement of the right hand in task execution was mandatory across all workstations and in both test runs.[2] The following three stations had to be completed (see *Figure 1*):

Station 1: Carry three boxes (weighing about 2 kg each) and several wooden plates of various sizes (< 1 kg each) over a distance of about three meters from one marked area to another.

Station 2: Tighten and loosen eight threaded wheels of two sizes on a wooden wall, use a ratchet screwdriver to tighten a prepared screw, and mark the edges of a small plate with a pencil while fixing the plate to the wooden wall.

Station 3: Use riveting pliers to anchor two rivets with a diameter of 3 mm and one rivet with a diameter of 4 mm in a prepared sheet-metal plate (different diameters require different amounts of force to anchor).

[2] Note that the experimental setup consisted of three stations, each of which addressed a task typically supported by the *Ironhand* exoskeleton (i.e., reflecting its range of applications according to the manufacturer's specifications, but with the lowest risk of injury). The work tasks were also selected in collaboration with the prospective supplier of the exoskeleton.

Figure 1. Participants completing Station 1 “carrying” (left), Station 2 “screwing” (center), and Station 3 “riveting” (right) with the *Ironhand* active hand exoskeleton.

After each test run, participants reported their experience by completing a tablet-based questionnaire as shown in *Appendix A*. Verbal statements during the task execution phase were not recorded and used for further analysis. Instead, we asked participants to comment on their experience in an open-ended section at the end of the questionnaires. Our intention was to collect additional qualitative information to better understand the response behavior retrospectively and shed light on noticeable problems with the exoskeleton. The examiner was present throughout the entire experiment to ensure that the tasks were properly performed and was available to answer questions, which were documented in writing. We fully debriefed participants immediately after the experiment and informed them about the actual aim and conditions of the study.

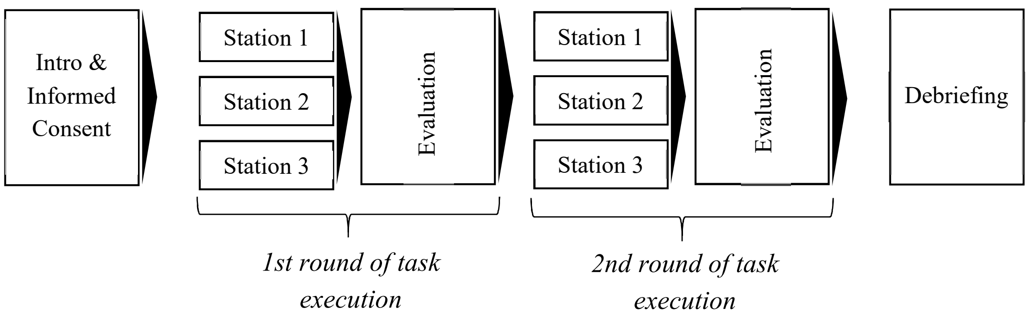

Figure 2. Experimental procedure.

4.4. The exoskeleton

In our study, we used the active hand exoskeleton *Ironhand* 2.0®, which was developed by Bioservo Technologies for industrial application. This commercially available device is supposed to assist with repetitive gripping movements and reduce grip-induced strain by decreasing the force needed to perform these work activities. Executing a firm and reliable grasp with less grip force, for example, when operating a tool such as a drill or sledgehammer, has the potential to conserve a worker's energy and to reduce fatigue. However, as an active system, the *Ironhand* exoskeleton also aims to provide additional strength and endurance to a user's hand-grip muscles. With a maximum weight of 2.6 kg, the modular system consists of a soft robotic glove with force sensors and artificial tendons, two arm straps, a control panel with a glove status indicator, and a power pack that uses a 15 V DC Li-ion stored in one of two carry solutions (Bioservo Technologies AB, 2021) – either in a backpack or in a rear-facing hip pocket. In our study, we used the hip pocket solution.

The *Ironhand* uses a cable-driven transmission system to implement the glove-closing mechanism. The robotic glove fully covers all fingers of one hand and integrates five force sensors located inside the distal phalanx. The sensors transmit real-time feedback to the power pack via a connector. A cable connects the remote control to the power pack for communication and power supply. When pressure is exerted on the force sensors of the glove, the control system in the power pack activates (i.e., activates an adjustable servo mechanism in response to sensor feedback) and pulls artificial tendons (cables) in the glove's fingers. A strong, controlled grasping motion is created that mimics the natural grasping movements of a healthy user's hand. The fabric and textiles selected and the cable routing on the glove are designed to ensure efficient and equal transfer of forces and torques to the fingers. The device allows individual configuration to meet a user's support needs or specific task requirements, but is not capable of supporting the opening of the palm. Safety instructions require a protective glove to be worn on top of the *Ironhand* exoskeleton.

4.5. Measures

The study used self-perception ratings of warmth, competence, machine-likeness, and attractiveness as dependent variables. After both test runs, participants were asked to think back to how they felt about themselves while performing the work tasks and answer the question "How would you describe yourself?" based on the following measures.

Self-perceived warmth. Following Meyer and Asbrock (2018), we used the SCM-based items *likable*, *warm,* and *good-natured* and let participants rate them on a five-point response scale (from 1 = *not at all* to 5 = *completely*). We averaged the items to obtain a measure of self-perceived warmth. The internal consistency reliability of the scale was quantified by calculating McDonald's Omega (ω)[3] (McDonald, 1999), with values between 0.70 and 0.95 being considered acceptable. The condition with exoskeleton formed a highly reliable index, as indicated by ω (HA) = 0.86, and the without-exoskeleton condition yielded comparatively moderate reliability (ω (HA) = 0.67).

Self-perceived competence. To form an index of self-perceived competence, we adapted the items *competent*, *competitive*, and *independent* from Meyer and Asbrock (2018) which were rated by means of five response options, from *not at all* (1) to *completely* (5). The Omega coefficient ω (HA) reached 0.71 for self-perceived competence in the condition with exoskeleton and 0.60 in the condition without exoskeleton usage.

Self-perceived machine-likeness. We assessed self-perceived machine-likeness with four pairs of polar adjectives (*unnatural* versus *natural*, *machine-like* versus *human-like*, *rigid in movement* versus *elegant in movement,* and *under external control* versus *under internal*

[3] We used the OMEGA macro (Hayes & Coutts, 2020) for SPSS, which allows calculating ω coefficients based on an alternative closed-form approach for estimating factor loadings described and discussed in Hancock and An (2020).

control) on a five-point scale. The items were adapted from the Anthropomorphism subscale from the Godspeed Questionnaire (Bartneck et al., 2009) and averaged to a scale of machine-likeness (ω_{with} (HA) = 0.76, ω_{without} (HA) = 0.72).

Self-perceived attractiveness. Participants reported on self-perceived attractiveness by rating themselves from *unattractive* to *attractive* on a five-point scale.

Intention to use. After participants had used the exoskeleton, we assessed their willingness to continue working with it. To this end, we administered the validated German Technology Usage Inventory (Kothgassner et al., 2013), which consists of items such as "I would use the exoskeleton beyond the study setting" ranked on a 7-point scale (from 1 = *not agree at all* to 7 = *very much agree*). The scale exhibited a high degree of reliability with a McDonald's Omega ω (HA) = .82.

5. Results

The statistics software SPSS (version 27) was used for data analysis. The strength of the relationships between variables of interest was analyzed via non-parametric Spearman's rank-order correlations (ρ). The correlations of all variables, means and standard deviations are presented in *Table 1*.

	M	SD	N	Correlations (Spearman's ρ)								
Variable				WARMTH	WARMTH exo	COMP	COMP exo	MLN	MLN exo	ATTRACT	ATTRACT exo	ITU
WARMTH	4.14	0.45	119	--								
$\text{WARMTH}_{\text{exo}}$	3.61	0.86	119	**.32*****	--							
COMP	4.06	0,48	119	.05	.12	--						
COMP_{exo}	4.17	0.52	119	.01	.12	**.33*****	--					
MLN	3.59	0.62	119	-.11	**-.18***	**-.35*****	-.10	--				
MLN_{exo}	4.63	0.84	119	-.08	**-.25****	-.09	**-.23***	.12	--			
ATTRACT	3.76	0.73	119	.08	.17	**.34*****	.17	**-.31*****	.01	--		
$\text{ATTRACT}_{\text{exo}}$	3.45	0.81	119	.01	**.35*****	.11	.15	-.05	-.12	**.48*****	--	
ITU	4.64	1.53	119	-.03	.06	.08	**.37*****	.01	**-.22***	.06	**.24****	--

Note. **p* < .05, ** *p* < .01, ****p* < .001 (2-tailed); exo = exoskeleton

Table 1. Descriptive statistics and zero-order intercorrelations between perceived warmth without exo (WARMTH), perceived warmth with exo (WARMTHexo), perceived competence without exo (COMP), perceived competence with exo (COMPexo), perceived machine-likeness without exo (MLN), perceived machine-likeness with exo (MLNexo), perceived attractiveness without exo (ATTRACT), perceived attractiveness with exo (ATTRACTexo), and intention to use (ITU).

With respect to the exoskeleton condition, initial zero-order correlations indicate that scores of reported warmth were strongly and positively associated with participants' attractiveness ratings ($\rho = .35$, $p < .001$) and negatively linked to perceptions of machine-likeness ($\rho = -.25$, $p = .006$). Participants who reported a higher perceived competence when wearing the exoskeleton felt less machine-like ($\rho = -.23$, $p = .012$) and were more willing to continue use of the exoskeleton (ITU), as indicated by a Spearman's $\rho = .37$, $p < .001$. Additionally, participants' behavioral intention to continue using the exoskeleton (ITU) is significantly interconnected with high attractiveness scores ($\rho = .24$, $p < .01$) and low perceived machine-likeness ($\rho = .22$, $p = .015$). Our analyses yielded no significant correlations between age or gender (all *p*s > .05).

We had hypothesized that individuals would perceive themselves as less warm (i.e., less likable, warm, and good-natured) but more competent when wearing the exoskeleton in performing their tasks. Ratings of self-perceived machine-likeness were assumed to be higher in the exoskeleton condition than in the condition without exoskeleton usage. For each comparison, a non-parametric Wilcoxon signed-ranks test for repeated-measures analysis was run. We set the threshold of significance at the standard value of $p < .05$, but adjusted the local α level in order to control for the family-wise error rate (FWER or alpha inflation) and thus account for multiple testing. We therefore applied the Bonferroni–Holm step-down procedure. The difference between evaluations of perceived warmth was highly significant ($T = 296.50$, $z = -6.27$, $p < .000$) and on average showed lower scores for exoskeleton usage ($Mdn = 3.67$, $M = 3.61$, $SD = .86$) than for not wearing the exoskeleton ($Mdn = 4.00$, $M = 4.14$, $SD = .45$). With $r_{warmth} = .57$, the effect size was found to be large (Gignac & Szodorai, 2016). Our initial assumption that using an active hand exoskeleton would have a negative effect on perceived warmth was therefore supported. Although the results yielded a statistically significant difference in perceived competence ($T = 2242.00$, $z = 2.08$, $p = .037$), the effect size of $r_{comp} = .19$ was small. Descriptively, perceived competence was rated slightly higher with the exoskeleton (Mdn = 4.00, M = 4.17, SD = .52) than without (Mdn = 4.00, M = 4.06, SD = .48). This trend is in line with our hypothesis, even though the group difference is only borderline significant[4]. Ratings of machine-likeness were on average significantly different between conditions (T = 5984.50, z = 8.20, $p < .000$), with participants feeling more machine-like with the exoskeleton (Mdn = 4.50, M = 4.63, SD = .84) than without it (Mdn = 3.50, M = 3.59, SD = .62). Considering the high significance level reached and the large effect size ($r_{mln} = .75$), the hypothesis for the exoskeleton-induced rise in machine-likeness is very well supported by our study. Further, our results show that wearing the exoskeleton had an influence on how attractive the users perceived themselves to be (T = 224.00, z = -4,13, $p < .000$; $r_{attract} = .38$). It appears that participants perceived themselves, on average, as less attractive with exoskeleton (Mdn = 3.00, M = 3.45, SD = .81) than without exoskeleton (Mdn = 4.00, M = 3.76, SD = .73). For a descriptive overview, changes in reported perceived warmth, competence, machine-likeness, and attractiveness (i.e., positive, zero, or negative difference values) between conditions with and without exoskeleton are shown in *Figure 3*.

[4] Note that the assumption of an increase in perceived competence mirrors a one-tailed hypothesis, which specifies a direction and thus requires $p < .025$ starting from a standard significance level of $p = .05$.

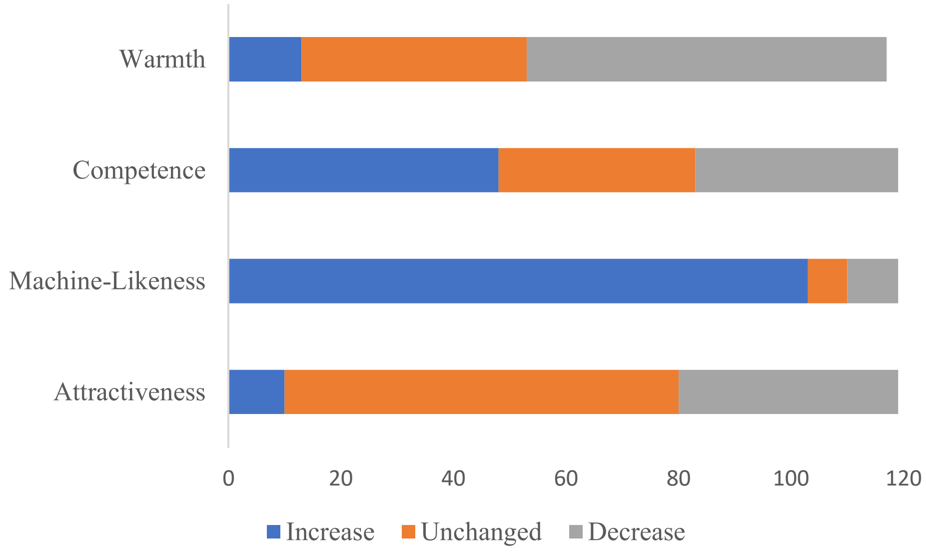

Figure 3. Absolute numbers of participants who showed a decrease, increase, or no change in the core variables as a result of wearing the exoskeleton.[5]

6. Discussion

In the workplace, exoskeletons are primarily intended to reduce the physical strain that demanding manual work activities impose on laborers (de Looze et al., 2016), but a look at the websites of various vendors of exoskeletons reveals that they are also touted as a means of enhancing workers' physical abilities and improving work performance. While the physical effects of occupational exoskeletons are increasingly studied and discussed (cf. Bär et al., 2021; Bock et al., 2022; Hoffmann et al., 2022; Mayer et al., 2022; Moeller et al., 2022; Zhu et al., 2021), their consequences for various facets of worker self-perception have received little attention within the overall debate about the technology's benefits and risks. Starting from existing concerns that wearable technology has the potential to dehumanize its users (Del Rio Carral et al., 2022; Tarbit et al., 2023; Veruggio et al., 2016), our study focused on gaining initial insights into how using a robotic exoskeleton affects self-perceived warmth, competence, attractiveness, and machine-likeness. Building on research that argues for

[5] For perceived warmth, perceived competence, and perceived machine-likeness, mean scale values were calculated for both conditions. Attractiveness was measured via a single item. For all four variables, we then calculated a difference score by subtracting the values of tEXO from tNO-EXO and categorized negative values (< 0) as a "decrease", 0 as "no change", and positive values as an "increase".

considering the non-utilitarian value of wearable technologies (Choi & Kim, 2016; Siedl & Mara, 2022), we also had a closer look at the effect of exoskeleton use on how attractive users felt. Further, we aimed to assess how these self-perceptions are correlated with participants' behavioral intention to keep using the exoskeleton. We thus conducted a within-subjects laboratory experiment in which participants performed several work tasks with and without the *Ironhand* exoskeleton.

We found that wearing an active hand exoskeleton resulted in a significant decrease in self-perceived warmth and significantly increased self-perceived machine-likeness for our study participants. With the exoskeleton, they tended to perceive themselves as more competent than without it. Taken together, the results of our study indicate a tendency to self-dehumanize when using the exoskeleton. Our research therefore provides the first evidence that, in addition to specific job characteristics (i.e., objectifying tasks) and the workplace social environment (i.e., objectification by others) (Baldissarri et al., 2022), modern wearable workplace technologies such as exoskeletons might make people feel a little more like machines. Since work is a key factor in identity formation (cf. Berkman, 2014; Stiglbauer & Batinic, 2012,), being forced to use a particular technology at work can be detrimental if it threatens our sense of worth as human beings. Previous research has already revealed negative outcomes of self-objectification in the workplace: For example, it diminishes beliefs in personal free will (Baldissarri et al., 2022) and promotes conforming behavior (Andrighetto et al., 2018) that involves suppressing one's feelings and personal values (Hewlin, 2009). In their research on organizational dehumanization, Caesens et al. (2017) found that workers who felt treated like mere instruments for organizational goal attainment experienced lower levels of work satisfaction, increased emotional exhaustion, and psychosomatic strain.

In line with our assumptions, wearing the exoskeleton made participants feel colder and more machine-like. Participants' perceptions of warmth and machine-likeness not only differed by condition (with exo vs. without exo), but were also negatively correlated: lower ratings of perceived warmth were linked to higher levels of machine-likeness. These findings accord with the concept of mechanistic dehumanization (Haslam, 2006) and contribute to the current discourse around the dehumanization of workers (Agadullina et al., 2022; Andrighetto et al., 2018; Baldissarri, Andrighetto, et al., 2017; Baldissarri et al., 2019; Bell & Khoury, 2016). Further, exoskeleton users who perceived higher levels of machine-likeness expressed less willingness to keep using the system[6].

Regarding self-perceived competence, our findings indicate a general tendency towards exoskeleton-induced competence gains. However, the role of self-perceived competence is not entirely clear-cut, which is also consistent with divergent psychological theories:

On the one hand, a person's perception of competence can be a source of intrinsic motivation and well-being, as discussed in the prominent Self-Determination Theory (Ryan & Deci, 2000). Recent research suggests competence as a basic psychological need to be fulfilled in the context of technology use (Moradbakhti et al., 2023). Experiencing personal effectiveness and mastery when executing a task, in turn, is supposed to contribute to positive self-efficacy beliefs (Schwarzer & Luszczynska, 2022), which are an important psychological resource (Xanthopoulou et al., 2007). Our study results show that gains in perceived competence are related to weaker feelings of machine-likeness. One might argue that an exoskeleton effectively boosting a person's sense of competence emphasizes personhood and thus contradicts self-objectification (cf. Loughnan et al., 2017.).

On the other hand, drawing on basic ideas from the Stereotype Content Model, the perception of competence can be situated within the framework of mechanistic dehumanization. It proposes that when others perceive individuals or groups as having bad intentions (low warmth), reinforcing their competence can further dehumanize them. In the

[6] According to Ajzen's (1991) Theory of Planned Behavior, a person's actions are determined by their intention (willingness) to perform a behavior. This theory is a key element in the field of *technology acceptance* research.

workplace context, one could argue that in accordance with the idea of „if you show you can do more, they will make you do more”, workers will link feeling personally more competent with increased work demands. This could emphasize a worker’s instrumentality (i.e., what they can be used for) (Nussbaum, 1995) and is closely related to the question of whether a natural human being is, ultimately, no longer “good enough”. If workers feel the pressure that they need to be technologically enhanced to become “more competent like a machine (or a cyborg)”, the question arises of whether this contributes to their dehumanized self-view. In any case, further research is needed to explore the interaction between perceptions of competence and self-dehumanization with respect to workers’ well-being in an organizational context.

We discovered a strong relationship between how competent individuals feel and their intention to use the exoskeleton. This is consistent with findings by Moradbakhti et al. (2022), who also suggested that perceived competence is a crucial factor in *technology acceptance*. Users’ increased sense of competence might shape how they perceive the two traditional key determinants of technology acceptance: *usefulness* and *ease of use* (F. D. Davis, 1989; Venkatesh & Bala, 2008; Venkatesh & Davis, 2000). Firstly, individuals who feel competent in executing their work tasks with the exoskeleton, could be more likely to recognize the benefits of the technology in enhancing their performance, which would lead to higher perceived usefulness ratings. Secondly, if users feel more competent with an exoskeleton, they may perceive it as easier to use, which in turn would increase their willingness to use the device.

Our experiment revealed that participants found themselves significantly less attractive when using the active hand exoskeleton. Lower personal attractiveness was associated with lower technology acceptance. These results support qualitative findings by Siedl and Mara (2022), who proposed *aesthetic appeal* as an important factor that influences a person's willingness to continue using exoskeletons in the workplace. However, while recent research hints at the hedonic value of attractiveness in "cool" consumer technologies (Sundar et al., 2014) and also at its relevance to individuals' intentions to use wearable devices (Chuah et al., 2016; Kim & Park, 2019), traditional models of technology acceptance do not yet take sufficient account of aesthetics.

7. Limitations and Outlook

To the best of our knowledge, there are very few exoskeleton field studies with larger (i.e., n > 100) sample sizes. In order to achieve such a high number of participants in our study, we decided to combine conducting a controlled laboratory experiment with actual use of an exoskeleton. As a result, our participants were not typical blue-collar workers, who are the target group for the use of occupational exoskeletons. To overcome this and increase transferability of our results, we invested great effort into developing test scenarios that involve work activities that resemble those typically performed in a carpentry workshop.

While our study provided preliminary insights into potentially dehumanizing self-perceptions related to exoskeleton use, we do not yet know much about interaction effects and the underlying mechanisms. Drawing on this limitation of our study, we have compiled a set of reflections that may inspire future research.

Firstly, previous studies documented the negative consequences of objectifying job features (e.g., high repetitiveness, fragmentation, and little personal control over work tasks, as considered by Baldissarri, Andrighetto, et al., 2017; Baldissarri et al., 2019). Interestingly, previous exoskeleton evaluation studies documented that exoskeletons specifically work well in providing support in repetitive tasks, such as lifting loads – precisely the kind of tasks that are assumed to be associated with worker objectification (Alemi et al., 2020; Madinei et al., 2020; Poliero et al., 2022). Bringing together these aspects in future studies would improve our understanding of the interplay between exoskeleton use and various levels of objectifying workplace tasks, and how it goes on to influence users' tendencies to dehumanize themselves. The interaction between objectifying work activities and the use of exoskeletons might reinforce workers' self-dehumanizing tendencies linked to raised performance goals. From a completely different perspective, however, implementing exoskeletons could be seen as a company's appreciation of its employees , for example, because employers spend considerable financial resources on modern assistive technologies or can convincingly claim that they are not interested in performance gains but in preventing long-term health damage to their employees (Siedl & Mara, 2022). The technology might thus even help to counteract workers' dehumanizing self-perceptions.

Secondly, it remains unclear under which conditions self-dehumanizing effects of technology use are stronger or weaker. Regarding exoskeletons, one may suggest that it is particularly their close proximity to the user's body which intensifies perceived self-dehumanization. Individuals who view exoskeletons primarily as practical work tools rather than as personal body enhancements and thus maintain a greater emotional distance might be less prone to feeling dehumanized.

Alternatively, one could theorize that employing exoskeletons reflects a lack of confidence in human capabilities to a broader extent. In such a scenario, exoskeletons would be just one of several work tools aimed to enhance employee performance. The compulsory use of AI tools such as *ChatGPT*, positioned as another method for augmenting human proficiency, would then also potentially contribute to a sense of dehumanization among users.

Additionally, differences between individuals might moderate the influence of exoskeleton use on perceived dehumanization in the workplace. Those with a higher need for support (e.g., who long for physical relief from physical problems), could be expected to be less likely to dehumanize themselves, as to them a positive health effect is paramount (Siedl & Mara, 2021). Based on our study observations, perception of competence appeared to be closely connected to the task-specific skills and prior experience of participants. They did not uniformly require assistance and differed in how well they managed to cope with the various work tasks. Therefore, one may infer that perceived competence when using an exoskeleton can be influenced by an individual's physical abilities, previous experiences, and prerequisites, including a personal need for support.

It is essential to note that the present study focused on only one specific type of active exoskeleton, which limits generalizability of the results. Future work could therefore replicate our study with other active exoskeleton devices and also investigate the effects of various design elements. Given what we know about the role of aesthetics in wearable technologies (Choi & Kim, 2016; Chuah et al., 2016; Dellon & Matsuoka, 2007; Tamari, 2017), various facets of system design (e.g., visual appearance, operating noise) might shape impressions among users and observers. Understanding how these aspects affect user self-perception from a psychological point of view could assist designers in improving the user experience and also contribute to user well-being.

Finally, we note that Haslam et al. (2005) observed that people ascribe positive human traits such as openness, warmth, and emotionality more to themselves than to others, even within their own social group. In other words, they rate themselves as more human than anyone else. Our study focused exclusively on gathering individuals' self-perceptions and did not incorporate self-assessments or external evaluations. Consideration of both of these should form part of further research. Given the potential to self-dehumanize as a result of using exoskeletons, we presume that there is a high probability that wearers can more easily become targets of dehumanizing behavior by others, including fellow workers.

8. Conclusion

The present study aimed to explore whether the use of exoskeletons leads to dehumanizing tendencies in individuals and affects perceived attractiveness of users. In a controlled lab experiment involving exoskeleton-assisted tasks, we found that wearing an active hand exoskeleton decreased participants' self-perceived warmth and increased their self-perceived machine-likeness. This suggests a potential shift in self-perception towards viewing oneself as more mechanical. Although using the exoskeleton increased perceived competence on average, it was negatively correlated with machine-likeness. The complex role of perceived competence in self-dehumanization becomes apparent, with gains not automatically contributing to a more mechanized view of self. Our study therefore highlights the need for further research into how workplace technologies such as exoskeletons affect individuals' dehumanizing self-perceptions and their consequences for workers' well-being. We further showed that perceived competence, perceived machine-likeness, and also personal attractiveness seem to matter in exoskeleton acceptance. By shedding light on perceived attractiveness, our study also underscores the need to consider aesthetic appeal in exoskeleton design. Ultimately, exoskeletons hold potential for improving workplace tasks, but their implications on individuals' perception of themselves as human beings must be carefully evaluated. This assessment is essential to ensuring a positive and respectful user experience on the one hand and the acceptance of these devices by those who (should) wear them on the other.

Appendix A

	Not at all	Very little	Somewhat	Much	Completely
warmth1: likable	☐ (1)	☐ (2)	☐ (3)	☐ (4)	☐ (5)
warmth2: warm	☐ (1)	☐ (2)	☐ (3)	☐ (4)	☐ (5)
warmth3: good-natured	☐ (1)	☐ (2)	☐ (3)	☐ (4)	☐ (5)

Table 2. Items used to measure perceived warmth with and without the exoskeleton (WARMTHexo/WARMTH).

	Not at all	Very little	Somewhat	Much	Completely
comp1: competent	☐ (1)	☐ (2)	☐ (3)	☐ (4)	☐ (5)
comp2: competitive	☐ (1)	☐ (2)	☐ (3)	☐ (4)	☐ (5)
comp3: independent	☐ (1)	☐ (2)	☐ (3)	☐ (4)	☐ (5)

Table 3. Items used to measure perceived competence with and without the exoskeleton (COMPexo/COMP**).**

mln1 $_{\text{inverted (R)}}$:	unnatural	☐ (1)	☐ (2)	☐ (3)	☐ (4)	☐ (5)	natural
mln2 $_{\text{inverted (R)}}$:	machine-like	☐ (1)	☐ (2)	☐ (3)	☐ (4)	☐ (5)	human-like
mln3 $_{\text{inverted (R)}}$:	rigid in movement	☐ (1)	☐ (2)	☐ (3)	☐ (4)	☐ (5)	elegant in movement
mln4 $_{\text{inverted (R)}}$:	under external control	☐ (1)	☐ (2)	☐ (3)	☐ (4)	☐ (5)	under internal control

Table 4. Items used to measure perceived machine-likeness with and without the exoskeleton (MLNexo/MLN).

attract:	unattractive	☐ (1)	☐ (2)	☐ (3)	☐ (4)	☐ (5)	attractive

Table 5. Item used to measure attractiveness with and without the exoskeleton (ATTRACTexo/ATTRACT).

	Not agree at all						Very much agree
itu1: I would use the exoskeleton beyond the study setting.	□ (1)	□ (2)	□ (3)	□ (4)	□ (5)	□ (6)	□ (7)
itu2: I would think about buying the exoskeleton.	□ (1)	□ (2)	□ (3)	□ (4)	□ (5)	□ (6)	□ (7)
itu3: I would like to have access to the exoskeleton.	□ (1)	□ (2)	□ (3)	□ (4)	□ (5)	□ (6)	□ (7)

Table 6. Items used to measure intention to use the exoskeleton (ITU).

References

Agadullina, E. R., Terskova, M. A., Erokhina, D. A., & Ankushev, V. V. (2022). Factors in workers' dehumanization: Multiple stigmatization, social status, and workers' sex. *The British Journal of Social Psychology*, *61*(4), 1101–1123. https://doi.org/10.1111/bjso.12528

Agarwal, P., & Deshpande, A. D. (2019). Exoskeletons. In *Human Performance Optimization* (pp. 234–259). Oxford University Press. https://doi.org/10.1093/oso/9780190455132.003.0011

Aggarwal, P., & McGill, A. L. (2007). Is that car smiling at me? Schema congruity as a basis for evaluating anthropomorphized products. *Journal of Consumer Research*, *34*(4), 468–479. https://doi.org/10.1086/518544

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, *50*(2), 179–211. https://doi.org/10.1016/0749-5978(91)90020-T

Alemi, M. M., Madinei, S., Kim, S [Sunwook], Srinivasan, D., & Nussbaum, M. A. (2020). Effects of two passive back-support exoskeletons on muscle activity, energy expenditure, and subjective assessments during repetitive lifting. *Human Factors*, *62*(3), 458–474. https://doi.org/10.1177/0018720819897669

Andrighetto, L., Baldissarri, C., Gabbiadini, A., Sacino, A., Valtorta, R. R., & Volpato, C. (2018). Objectified conformity: working self-objectification increases conforming behavior. *Social Influence*, *13*(2), 78–90. https://doi.org/10.1080/15534510.2018.1439769

Andrighetto, L., Baldissarri, C., & Volpato, C. (2017). (Still) Modern Times : Objectification at work. *European Journal of Social Psychology*, *47*(1), 25–35. https://doi.org/10.1002/ejsp.2190

Babič, J., Laffranchi, M., Tessari, F., Verstraten, T., Novak, D., Šarabon, N., Ugurlu, B., Peternel, L., Torricelli, D., & Veneman, J. F. (2021). Challenges and solutions for application and wider adoption of wearable robots. *Wearable Technologies*, *2.* https://doi.org/10.1017/wtc.2021.13

Baldissarri, C., Andrighetto, L., Gabbiadini, A., & Volpato, C. (2017). Work and freedom? Working self-objectification and belief in personal free will. *The British Journal of Social Psychology*, *56*(2), 250–269. https://doi.org/10.1111/bjso.12172

Baldissarri, C., Andrighetto, L., & Volpato, C. (2014). When work does not ennoble man: Psychological consequences of working objectification. *TPM. Testing, Psychometrics, Methodology in Applied Psychology*, *21*(3), 327–339. https://doi.org/10.4473/TPM21.3.7

Baldissarri, C., Andrighetto, L., & Volpato, C. (2019). Feeling like an object: A field study on working self-objectification and belief in personal free will. *TPM. Testing, Psychometrics, Methodology in Applied Psychology*, *26*(2), 185–197.

Baldissarri, C., Andrighetto, L., & Volpato, C. (2022). The longstanding view of workers as objects: antecedents and consequences of working objectification. *European Review of Social Psychology*, *33*(1), 81–130. https://doi.org/10.1080/10463283.2021.1956778

Baldissarri, C., Valtorta, R. R., Andrighetto, L., & Volpato, C. (2017). Workers as objects: The nature of working objectification and the role of perceived alienation. *TPM. Testing, Psychometrics, Methodology in Applied Psychology*, *24*(2), 153–166. https://doi.org/10.4473/TPM24.2.1

Baltrusch, S. J., Houdijk, H., van Dieën, J. H., van Bennekom, C. A. M., & de Kruif, A. J. T. C. M. (2020). Perspectives of end users on the potential use of trunk exoskeletons for people with low-back pain: A focus group study. *Human Factors*, *62*(3), 365–376. https://doi.org/10.1177/0018720819885788

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review*, *84*(2), 191–215. https://doi.org/10.1037/0033-295X.84.2.191

Bandura, A. (1986). *Social foundations of thought and action: a social cognitive theory*. Prentice-Hall. https://psycnet.apa.org/record/1985-98423-000

Bär, M., Steinhilber, B., Rieger, M. A., & Luger, T. (2021). The influence of using exoskeletons during occupational tasks on acute physical stress and strain compared to no exoskeleton - A systematic review and meta-analysis. *Applied Ergonomics*, *94*, 103385. https://doi.org/10.1016/j.apergo.2021.103385

Barbaranelli, C., Fida, R., Paciello, M., & Tramontano, C. (2018). 'Possunt, quia posse videntur': They can because they think they can. Development and validation of the Work Self-Efficacy scale: Evidence from two studies. *Journal of Vocational Behavior*, *106*, 249–269. https://doi.org/10.1016/j.jvb.2018.01.006

Bartneck, C., Kulić, D., Croft, E., & Zoghbi, S. (2009). Measurement instruments for the anthropomorphism, animacy, likeability, perceived intelligence, and perceived safety of robots. *International Journal of Social Robotics*, *1*(1), 71–81. https://doi.org/10.1007/s12369-008-0001-3

Bastian, B., & Haslam, N. (2010). Excluded from humanity: The dehumanizing effects of social ostracism. *Journal of Experimental Social Psychology*, *46*(1), 107–113. https://doi.org/10.1016/j.jesp.2009.06.022

Bastian, B., & Haslam, N. (2011). Experiencing dehumanization: Cognitive and emotional effects of everyday dehumanization. *Basic and Applied Social Psychology*, *33*(4), 295–303. https://doi.org/10.1080/01973533.2011.614132

Beas, M. I., & Salanova, M. (2006). Self-efficacy beliefs, computer training and psychological well-being among information and communication technology workers. *Computers in Human Behavior*, *22*(6), 1043–1058. https://doi.org/10.1016/j.chb.2004.03.027

Bell, C. M., & Khoury, C. (2011). Dehumanization, deindividuation, anomie and organizational justice. In S. Gilliland, S. Dirk, & S. Daniel (Eds.), *Emerging Perspectives on Organizational Justice and Ethics, Research in Social Issues in Management* (Vol. 7, pp. 169–200). Information Age Publishing.

Bell, C. M., & Khoury, C. (2016). Organizational powerlessness, dehumanization, and gendered effects of procedural justice. *Journal of Managerial Psychology*, *31*(2), 570–585. https://doi.org/10.1108/JMP-09-2014-0267

Berkman, L. F. (2014). Commentary: The hidden and not so hidden benefits of work: Identity, income and interaction. *International Journal of Epidemiology*, *43*(5), 1517–1519. https://doi.org/10.1093/ije/dyu110

Bioservo Technologies AB. (2021). *Ironhand® User Manual: TYPE: A1*. Bioservo Technologies AB.

Blanchy, K. B., Bouchard, C., Bonnardel, N., Lockner, D., & Aoussat, A. (2015). User experience dimensions in product design: a consolidation of what academic researchers know and what design practitioners do. *Journal of Design Research*, *13*(2), 107–124. https://doi.org/10.1504/JDR.2015.069754

Bock, S. de, Ghillebert, J., Govaerts, R., Tassignon, B., Rodriguez-Guerrero, C., Crea, S., Veneman, J., Geeroms, J., Meeusen, R., & Pauw, K. de (2022). Benchmarking occupational exoskeletons: An evidence mapping systematic review. *Applied Ergonomics*, *98*, 103582. https://doi.org/10.1016/j.apergo.2021.103582

Bogue, R. (2018). Exoskeletons – a review of industrial applications. *Industrial Robot: An International Journal*, *45*(5), 585–590. https://doi.org/10.1108/IR-05-2018-0109

Bützer, T., Lambercy, O., Arata, J., & Gassert, R. (2021). Fully wearable actuated soft exoskeleton for grasping assistance in everyday activities. *Soft Robotics*, *8*(2), 128–143. https://doi.org/10.1089/soro.2019.0135

Caesens, G., Stinglhamber, F., Demoulin, S., & Wilde, M. de (2017). Perceived organizational support and employees' well-being: the mediating role of organizational dehumanization. *European Journal of Work and Organizational Psychology*, *26*(4), 527–540. https://doi.org/10.1080/1359432X.2017.1319817

Cha, J. S., Monfared, S., Stefanidis, D., Nussbaum, M. A., & Yu, D. (2020). Supporting surgical teams: Identifying needs and barriers for exoskeleton implementation in the operating room. *Human Factors*, *62*(3), 377–390. https://doi.org/10.1177/0018720819879271

Choi, J., & Kim, S [Seongcheol] (2016). Is the smartwatch an IT product or a fashion product? A study on factors affecting the intention to use smartwatches. *Computers in Human Behavior*, *63*, 777–786. https://doi.org/10.1016/j.chb.2016.06.007

Christoff, K. (2014). Dehumanization in organizational settings: Some scientific and ethical considerations. *Frontiers in Human Neuroscience*, *8*, 748. https://doi.org/10.3389/fnhum.2014.00748

Chuah, S. H.-W., Rauschnabel, P. A., Krey, N., Nguyen, B., Ramayah, T., & Lade, S. (2016). Wearable technologies: the role of usefulness and visibility in smartwatch adoption. *Computers in Human Behavior*, *65*, 276–284. https://doi.org/10.1016/j.chb.2016.07.047

Cuddy, A. J. C., Fiske, S. T., & Glick, P. (2007). The BIAS map: Behaviors from intergroup affect and stereotypes. *Journal of Personality and Social Psychology*, *92*(4), 631–648. https://doi.org/10.1037/0022-3514.92.4.631

Cuddy, A. J. C., Fiske, S. T., & Glick, P. (2008). Warmth and competence as universal dimensions of social perception: The Stereotype Content Model and the BIAS Map. In M. P. Zanna (Ed.), *Advances in Experimental Social Psychology* (Vol. 40, pp. 61–149). Elsevier. https://doi.org/10.1016/S0065-2601(07)00002-0

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, *13*(3), 319–340. https://doi.org/10.2307/249008

Davis, K. G., Reid, C. R., Rempel, D. D., & Treaster, D. (2020). Introduction to the human factors special issue on user-centered design for exoskeleton. *Human Factors*, *62*(3), 333–336. https://doi.org/10.1177/0018720820914312

de Looze, M. P., Bosch, T., Krause, F., Stadler, K. S., & O'Sullivan, L. W. (2016). Exoskeletons for industrial application and their potential effects on physical work load. *Ergonomics*, *59*(5), 671–681. https://doi.org/10.1080/00140139.2015.1081988

Del Rio Carral, M., Bourqui, V., Vuilleumier, N., Ortieb, A., & Bouri, M. (2022). Are functional measures sufficient to capture acceptance? A qualitative study on lower limb exoskeleton use for older people. *International Journal of Social Robotics*, *14*(3), 603–616. https://doi.org/10.1007/s12369-021-00810-9

Dellon, B., & Matsuoka, Y. (2007). Prosthetics, exoskeletons, and rehabilitation [Grand Challenges of Robotics]. *IEEE Robotics & Automation Magazine*, *14*(1), 30–34. https://doi.org/10.1109/MRA.2007.339622

Epley, N., Waytz, A., & Cacioppo, J. T. (2007). On seeing human: A three-factor theory of anthropomorphism. *Psychological Review*, *114*(4), 864–886. https://doi.org/10.1037/0033-295X.114.4.864

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*(2), 175–191. https://doi.org/10.3758/BF03193146

Ferreira, J. J., Fernandes, C. I., Rammal, H. G., & Veiga, P. M. (2021). Wearable technology and consumer interaction: A systematic review and research agenda. *Computers in Human Behavior*, *118*, 106710. https://doi.org/10.1016/j.chb.2021.106710

Fiske, S. T. (2009). From dehumanization and objectification to rehumanization: Neuroimaging studies on the building blocks of empathy. *Annals of the New York Academy of Sciences*, *1167*, 31–34. https://doi.org/10.1111/j.1749-6632.2009.04544.x

Fiske, S. T., Cuddy, A. J. C., & Glick, P. (2007). Universal dimensions of social cognition: Warmth and competence. *Trends in Cognitive Sciences*, *11*(2), 77–83. https://doi.org/10.1016/j.tics.2006.11.005

Fiske, S. T., Cuddy, A. J. C., Glick, P., & Xu, J. (2002). A model of (often mixed) stereotype content: Competence and warmth respectively follow from perceived status and competition. *Journal of Personality and Social Psychology*, *82*(6), 878–902. https://doi.org/10.1037/0022-3514.82.6.878

Gignac, G. E., & Szodorai, E. T. (2016). Effect size guidelines for individual differences researchers. *Personality and Individual Differences*, *102*, 74–78. https://doi.org/10.1016/j.paid.2016.06.069

Gilotta, S., Spada, S., Ghibaudo, L., Isoardi, M., & Mosso, C. O. (2019). Acceptability beyond usability: A manufacturing case study. In S. Bagnara, R. Tartaglia, S. Albolino, T. Alexander, & Y. Fujita (Eds.), *Advances in Intelligent Systems and Computing. Proceedings of the 20th Congress of the International Ergonomics Association (IEA 2018)* (Vol. 824, pp. 922–934). Springer International Publishing. https://doi.org/10.1007/978-3-319-96071-5_95

Gorgey, A. S. (2018). Robotic exoskeletons: The current pros and cons. *World Journal of Orthopedics*, *9*(9), 112–119. https://doi.org/10.5312/wjo.v9.i9.112

Greenbaum, D. (2016). Ethical, legal and social concerns relating to exoskeletons. *ACM SIGCAS Computers and Society*, *45*(3), 234–239. https://doi.org/10.1145/2874239.2874272

Grewal, D., Kroschke, M., Mende, M., Roggeveen, A. L., & Scott, M. L. (2020). Frontline cyborgs at your service: How human enhancement technologies affect customer experiences in retail, sales, and service settings. *Journal of Interactive Marketing*, *51*, 9–25. https://doi.org/10.1016/j.intmar.2020.03.001

Groos, S., Fuchs, M., & Kluth, K. (2020). Determination of the subjective strain experiences during assembly activities using the exoskeleton “Chairless Chair”. In J. Chen (Ed.), *Advances in Intelligent Systems and Computing. Advances in human factors in robots and unmanned systems* (Vol. 962, pp. 72–82). Springer International Publishing. https://doi.org/10.1007/978-3-030-20467-9_7

Gruenfeld, D. H., Inesi, M. E., Magee, J. C., & Galinsky, A. D. (2008). Power and the objectification of social targets. *Journal of Personality and Social Psychology*, *95*(1), 111–127. https://doi.org/10.1037/0022-3514.95.1.111

Haraway, D. (1991). *Simians, cyborgs, and women: The reinvention of nature*. Routledge.

Haslam, N. (2006). Dehumanization: An integrative review. *Personality and Social Psychology Review*, *10*(3), 252–264. https://doi.org/10.1207/s15327957pspr1003_4

Haslam, N., & Bain, P. (2007). Humanizing the self: Moderators of the attribution of lesser humanness to others. *Personality & Social Psychology Bulletin*, *33*(1), 57–68. https://doi.org/10.1177/0146167206293191

Haslam, N., Bain, P., Douge, L., Lee, M., & Bastian, B. (2005). More human than you: Attributing humanness to self and others. *Journal of Personality and Social Psychology*, *89*(6), 937–950. https://doi.org/10.1037/0022-3514.89.6.937

Haslam, N., Bastian, B., & Bissett, M. (2004). Essentialist beliefs about personality and their implications. *Personality & Social Psychology Bulletin*, *30*(12), 1661–1673. https://doi.org/10.1177/0146167204271182

Haslam, N., Kashima, Y., Loughnan, S [Stephen], Shi, J., & Suitner, C. (2008). Subhuman, inhuman, and superhuman: Contrasting humans with nonhumans in three cultures. *Social Cognition*, *26*(2), 248–258. https://doi.org/10.1521/soco.2008.26.2.248

Haslam, N., Loughnan, S [Stephen], Reynolds, C., & Wilson, S. (2007). Dehumanization: A new perspective. *Social and Personality Psychology Compass*, *1*(1), 409–422. https://doi.org/10.1111/j.1751-9004.2007.00030.x

Hewlin, P. F. (2009). Wearing the cloak: Antecedents and consequences of creating facades of conformity. *The Journal of Applied Psychology*, *94*(3), 727–741. https://doi.org/10.1037/a0015228

Hoffmann, N., Prokop, G., & Weidner, R. (2022). Methodologies for evaluating exoskeletons with industrial applications. *Ergonomics*, *65*(2), 276–295. https://doi.org/10.1080/00140139.2021.1970823

Huysamen, K., Looze, M. de, Bosch, T., Ortiz, J., Toxiri, S., & O'Sullivan, L. W. (2018). Assessment of an active industrial exoskeleton to aid dynamic lifting and lowering manual handling tasks. *Applied Ergonomics*, *68*, 125–131. https://doi.org/10.1016/j.apergo.2017.11.004

Kim, J., & Park, E. (2019). Beyond coolness: Predicting the technology adoption of interactive wearable devices. *Journal of Retailing and Consumer Services*, *49*, 114–119. https://doi.org/10.1016/j.jretconser.2019.03.013

Kothgassner, O. D., Felnhofer, A., Hauk, N., Kastenhofer, E., Gomm, J., & Kryspin-Exner, I. (2013). *TUI: Technology usage inventory*. ICARUS.

Kuber, P. M., & Rashedi, E. (2021). Product ergonomics in industrial exoskeletons: Potential enhancements for workforce efficiency and safety. *Theoretical Issues in Ergonomics Science*, *22*(6), 729–752. https://doi.org/10.1080/1463922X.2020.1850905

Lai, A.-L. (2012). Cyborg as commodity: Exploring conception of self-identity, body and citizenship within the context of emerging transplant technologies. In Z. Gürhan-Canli, C. Otnes, R. Zhu, & D. MN (Eds.), *NA - Advances in Consumer Research* (pp. 386–394).

Loughnan, S [Steve], Baldissarri, C., Spaccatini, F., & Elder, L. (2017). Internalizing objectification: Objectified individuals see themselves as less warm, competent, moral, and human. *The British Journal of Social Psychology*, *56*(2), 217–232. https://doi.org/10.1111/bjso.12188

Lowe, B. D., Billotte, W. G., & Peterson, D. R. (2019). Astm F48 formation and standards for industrial exoskeletons and exosuits. *IISE Transactions on Occupational Ergonomics and Human Factors*, *7*, 230–236. https://doi.org/10.1080/24725838.2019.1579769

Lu, L., Zhang, J., Xie, Y., Gao, F., Xu, S., Wu, X., & Ye, Z. (2020). Wearable health devices in health care: Narrative systematic review. *JMIR MHealth and UHealth*, *8*(11), e18907. https://doi.org/10.2196/18907

Lum, H. C. (2021). Exploring technology tendencies and their impact on human-human interactions. In D. Khosrow-Pour & H. Lum (Eds.), *Advances in Human and Social Aspects of Technology. Human Factors Issues and the Impact of Technology on Society* (pp. 222–238). IGI Global. https://doi.org/10.4018/978-1-7998-6453-0.ch010

Lum, H. C., Shelstad, W. J., Harris, M. H., & White, M. M. (2014). Human or superhuman. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *58*(1), 1424–1428. https://doi.org/10.1177/1541931214581297

Lum, H. C., Sims, V. K., Chin, M. G., Halse, S. E., & Harris, M. A. (2012). Humans to robots: How technomorphic features shape our perceptions of each other. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *56*(1), 1534–1538. https://doi.org/10.1177/1071181312561305

Ma, J., Ollier-Malaterre, A., & Lu, C. (2021). The impact of techno-stressors on work–life balance: The moderation of job self-efficacy and the mediation of emotional exhaustion. *Computers in Human Behavior*, *122*, 106811. https://doi.org/10.1016/j.chb.2021.106811

Madinei, S., Alemi, M. M., Kim, S [Sunwook], Srinivasan, D., & Nussbaum, M. A. (2020). Biomechanical assessment of two back-support exoskeletons in symmetric and asymmetric repetitive lifting with moderate postural demands. *Applied Ergonomics*, *88*, 103156. https://doi.org/10.1016/j.apergo.2020.103156

Mandl, S., Bretschneider, M., Meyer, S., Gesmann-Nuissl, D., Asbrock, F., Meyer, B., & Strobel, A. (2022). Embodied digital technologies: First insights in the social and legal perception of robots and users of prostheses. *Frontiers in Robotics and AI*, *9*, 787970. https://doi.org/10.3389/frobt.2022.787970

Maslach, C., Schaufeli, W. B., & Leiter, M. P. (2001). Job Burnout. *Annual Review of Psychology*, *52*, 397–422. https://doi.org/10.1146/annurev.psych.52.1.397

Maurice, P., Allienne, L., Malaise, A., & Ivaldi, S. (2018). Ethical and social considerations for the introduction of human-centered technologies at work. In *2018 IEEE Workshop on Advanced Robotics and its Social Impacts (ARSO)* (pp. 131–138). IEEE. https://doi.org/10.1109/ARSO.2018.8625830

Mayer, T. A., Harsch, A.-K., Koska, D., Hensel-Unger, R., & Maiwald, C. (2022). Effects of an active hand exoskeleton on forearm muscle activity in industrial assembly grips. *Work*, *72*(4), 1577–1591. https://doi.org/10.3233/WOR-211272

McDonald, R. P. (1999). *Test theory: A unified treatment.* Lawrence Erlbaum.

Meyer, B., & Asbrock, F. (2018). Disabled or cyborg? How bionics affect stereotypes toward people with physical disabilities. *Frontiers in Psychology*, *9*, 2251. https://doi.org/10.3389/fpsyg.2018.02251

Moeller, T., Krell-Roesch, J., Woll, A., & Stein, T. (2022). Effects of upper-limb exoskeletons designed for use in the working environment - A literature review. *Frontiers in Robotics and AI*, *9*, 858893. https://doi.org/10.3389/frobt.2022.858893

Montague, A., & Matson, F. W. (1983). *The dehumanization of man* (1st ed.). McGraw-Hill.

Moore, D., Tennent, H., Martelaro, N., & Ju, W. (2017). Making noise intentional. In B. Mutlu, M. Tscheligi, A. Weiss, & J. E. Young (Eds.), *Proceedings of the 2017 ACM/IEEE International Conference on Human-Robot Interaction* (pp. 12–21). ACM. https://doi.org/10.1145/2909824.3020238

Moradbakhti, L., Leichtmann, B., & Mara, M. (2023). Development and validation of a basic psychological needs scale for technology use [*Manuscript Submitted for Publication]*, LIT Robopsychology Lab, Johannes Kepler University Linz.

Moradbakhti, L., Schreibelmayr, S., & Mara, M. (2022). Do Men Have No Need for "Feminist" Artificial Intelligence? Agentic and Gendered Voice Assistants in the Light of Basic Psychological Needs. *Frontiers in Psychology*, *13*, 855091. https://doi.org/10.3389/fpsyg.2022.855091

Nussbaum, M. C. (1995). Objectification. *Philosophy & Public Affairs*, *24*(4), 249–291. https://doi.org/10.1111/j.1088-4963.1995.tb00032.x

Olarte-Pascual, C., Pelegrín-Borondo, J., Reinares-Lara, E., & Arias-Oliva, M. (2021). From wearable to insideable: Is ethical judgment key to the acceptance of human capacity-enhancing intelligent technologies? *Computers in Human Behavior*, *114*, 106559. https://doi.org/10.1016/j.chb.2020.106559

Pelegrín-Borondo, J., Reinares-Lara, E., & Olarte-Pascual, C. (2017). Assessing the acceptance of technological implants (the cyborg): Evidences and challenges. *Computers in Human Behavior*, *70*, 104–112. https://doi.org/10.1016/j.chb.2016.12.063

Poliero, T., Fanti, V., Sposito, M., Caldwell, D. G., & Di Natali, C. (2022). Active and passive back-support exoskeletons: A comparison in static and dynamic tasks. *IEEE Robotics and Automation Letters*, *7*(3), 8463–8470. https://doi.org/10.1109/LRA.2022.3188439

Pons, J. L., Ceres, R., & Calderón, L. (2008). Introduction to wearable robotics. In J. L. Pons (Ed.), *Wearable robots: Biomechatronic exoskeletons* (pp. 1–16). Wiley.

Proud, J. K., Lai, D. T. H., Mudie, K. L., Carstairs, G. L., Billing, D. C., Garofolini, A., & Begg, R. K. (2022). Exoskeleton application to military manual handling tasks. *Human Factors*, *64*(3), 527–554. https://doi.org/10.1177/0018720820957467

Raisamo, R., Rakkolainen, I., Majaranta, P., Salminen, K., Rantala, J., & Farooq, A. (2019). Human augmentation: Past, present and future. *International Journal of Human-Computer Studies*, *131*, 131–143. https://doi.org/10.1016/j.ijhcs.2019.05.008

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *The American Psychologist*, *55*(1), 68–78. https://doi.org/10.1037/0003-066X.55.1.68

Shore, L., Power, V., Hartigan, B., Schülein, S., Graf, E., Eyto, A. de, & O'Sullivan, L. (2020). Exoscore: A design tool to evaluate factors associated with technology acceptance of soft lower limb exosuits by older adults. *Human Factors*, *62*(3), 391–410. https://doi.org/10.1177/0018720819868122

Siedl, S. M., & Mara, M. (2021). Exoskeleton acceptance and its relationship to self-efficacy enhancement, perceived usefulness, and physical relief: A field study among logistics workers. *Wearable Technologies*, *2*(e10). https://doi.org/10.1017/wtc.2021.10

Siedl, S. M., & Mara, M. (2022). What Drives Acceptance of Occupational Exoskeletons? Focus Group Insights from Workers in Food Retail and Corporate Logistics. *International Journal of Human-Computer Interaction*, 1–10. https://doi.org/10.1080/10447318.2022.2108969

Siedl, S. M., Wolf, M., & Mara, M. (2021). Exoskeletons in the supermarket: Influences of comfort, strain relief and task-technology fit on retail workers' post-trial intention to use. In C. Bethel, A. Paiva, E. Broadbent, D. Feil-Seifer, & D. Szafir (Eds.), *Proceedings of the 2021 ACM/IEEE International Conference on Human-Robot Interaction* (pp. 397–401). ACM. https://doi.org/10.1145/3434074.3447200

Steinhilber, B., Luger, T., Schwenkreis, P., Middeldorf, S., Bork, H., Mann, B., Glinski, A. von, Schildhauer, T. A., Weiler, S., Schmauder, M., Heinrich, K., Winter, G., Schnalke, G., Frener, P., Schick, R., Wischniewski, S., & Jäger, M. (2020). The use of exoskeletons in the occupational context for primary, secondary, and tertiary prevention of work-related musculoskeletal complaints. *IISE Transactions on Occupational Ergonomics and Human Factors*, *8*(3), 132–144. https://doi.org/10.1080/24725838.2020.1844344

Stiglbauer, B., & Batinic, B. (2012). The role of Jahoda's latent and financial benefits for work involvement: A longitudinal study. *Journal of Vocational Behavior*, *81*(2), 259–268. https://doi.org/10.1016/j.jvb.2012.07.008

Tamari, T. (2017). Body image and prosthetic aesthetics. *Body & Society*, *23*(2), 25–56. https://doi.org/10.1177/1357034X17697364

Tarbit, J., Hartley, N., & Previte, J. (2023). Exoskeletons at your service: A multi-disciplinary structured literature review. *Journal of Services Marketing*, *37*(3), 313–339. https://doi.org/10.1108/JSM-02-2022-0045

Thalman, C., & Artemiadis, P. (2020). A review of soft wearable robots that provide active assistance: Trends, common actuation methods, fabrication, and applications. *Wearable Technologies*, *1*(e3). https://doi.org/10.1017/wtc.2020.4

Toxiri, S., Koopman, A. S., Lazzaroni, M., Ortiz, J., Power, V., Looze, M. P. de, O'Sullivan, L., & Caldwell, D. G. (2018). Rationale, implementation and evaluation of assistive strategies for an active back-support exoskeleton. *Frontiers in Robotics and AI*, *5*, 53. https://doi.org/10.3389/frobt.2018.00053

Upasani, S., Franco, R., Niewolny, K., & Srinivasan, D. (2019). The potential for exoskeletons to improve health and safety in agriculture—perspectives from service providers. *IISE Transactions on Occupational Ergonomics and Human Factors*, *7*(3-4), 222–229. https://doi.org/10.1080/24725838.2019.1575930

Valtorta, R. R., & Monaci, M. G. (2023). When workers feel like objects: A field study on self-objectification and affective organizational commitment. *Europe's Journal of Psychology*, *19*(1), 15–26. https://doi.org/10.5964/ejop.5549

Venkatesh, V., & Bala, H. (2008). Technology Acceptance Model 3 and a research agenda on interventions. *Decision Sciences*, *39*(2), 273–315. https://doi.org/10.1111/j.1540-5915.2008.00192.x

Venkatesh, V., & Davis, F. D. (2000). A theoretical extension of the Technology Acceptance Model: Four longitudinal field studies. *Management Science*, *46*(2), 186–204. https://doi.org/10.1287/mnsc.46.2.186.11926

Veruggio, G., Operto, F., & Bekey, G. (2016). Roboethics: Social and ethical implications. In B. Siciliano & O. Khatib (Eds.), *Springer Handbook of Robotics* (pp. 2135–2160). Springer International Publishing. https://doi.org/10.1007/978-3-319-32552-1_80

Vogt, W. P., & Johnson, R. B. (2011). *Dictionary of statistics & methodology: A nontechnical guide for the social sciences* (4th ed.). Sage.

Xanthopoulou, D., Bakker, A. B., Demerouti, E., & Schaufeli, W. B. (2007). The role of personal resources in the job demands-resources model. *International Journal of Stress Management*, *14*(2), 121–141. https://doi.org/10.1037/1072-5245.14.2.121

Zhu, Z., Dutta, A., & Dai, F. (2021). Exoskeletons for manual material handling – A review and implication for construction applications. *Automation in Construction*, *122*, 103493. https://doi.org/10.1016/j.autcon.2020.103493