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EMOTIONAL EXPERIENCE AND ACCEPTANCE OF PASSIVE EXOSKELETONS IN HEALTHCARE SECTOR: INSIGHTS FROM A HUMAN-CENTERED DESIGN APPROACH

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ABSTRACT

Wearable exoskeletons hold promise for reducing the physical strain of healthcare workers, yet their emotional and experiential impact remains underexplored. This study, part of the Exo.Care program, investigated healthcare workers' emotional responses and user experience during a 30-day trial of a passive exoskeleton in residential and home-care settings. Using the Geneva Emotion Wheel (GEW) and the User Experience Questionnaire (UEQ), results showed that initial interactions elicited predominantly positive emotions, such as interest and admiration, reflecting the novelty effect. After prolonged use, positive emotional intensity decreased, while fear and disappointment emerged, highlighting gaps between expectations and actual performance. UEQ results revealed usability challenges in efficiency, dependability, and stimulation, though novelty and attractiveness were positively rated. Findings underscore the importance of integrating emotional and ergonomic factors in exoskeleton design to enhance acceptability, facilitate adoption, and ensure these devices can be effectively incorporated into healthcare workflows.

INTRODUCTION

The aging population and growing demand for continuous care increase the physical workload for healthcare workers, particularly those who transfer and move patients within healthcare facilities. Recent trends in research and development in wearable robotics applied to the healthcare sector (Vallée et al., 2024) suggest that exoskeletons can improve work procedures, reducing fatigue and injuries among operators (Latina et al., 2020; Petrini et al., 2019) and improving the care service for patients. Despite its potential, exoskeleton technology brings with it numerous challenges, such as poor environmental adherence, high development costs, resistance to technological adoption due to its limited use, and, finally, psychosocial, organizational, and emotional aspects of acceptance. The scientific literature on wearable technologies—particularly upper-limb assistive exoskeletons—focuses primarily on biomechanical, engineering, and control-related aspects (Gull et al., 2021; Mahfouz et al., 2024; Gull, Bai & Bak, 2020; Tian et al., 2024; Galbert & Buis,

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2024). Studies address issues such as accurate modeling of the human arm's degrees of freedom, the selection of lightweight and compliant actuation systems—such as pneumatic artificial muscles or cable-driven mechanisms—and the development of advanced control strategies, often based on decoding motor intentions through physiological signals (sEMG, EEG). These studies demonstrate a significant effort to improve device effectiveness, portability, and usability across clinical and industrial environments. However, despite the breadth and rigor of technical studies, the role of emotions in the interaction between users and exoskeletons remains surprisingly underexplored. Yet this is a crucial dimension: emotional perception of the device directly affects acceptability, willingness to use, and the integration of the exoskeleton into daily work practices. The emotional experience can either support or hinder a calm, natural, and lasting interaction with the technology, substantially shaping its real-world effectiveness in care and work settings. The design—particularly experience-oriented ergonomic design—can play a decisive role in addressing this gap. Research in medical design has long emphasized that emotional factors—such as perceived control, dignity, aesthetic familiarity, and non-stigmatization—are essential for the adoption and sustained use of assistive technologies (Norman, 2004; McCarthy & Wright, 2004; Desmet & Hekkert, 2007). In adjacent fields such as orthotics and prosthetics, physical rehabilitation, and daily living aids, numerous studies have shown that assessing emotional impact enables the creation of devices that are more welcoming, less intrusive, and capable of fostering an empathetic relationship between user and technology (Iacono, 2022). Aesthetic perception, familiarity of form, the sense of safety, and a device's ability to avoid making users feel "ill" or "dependent" are also fundamental variables influencing adoption and consistent use. Factors such as users' sense of identity (Shinohara & Wobbrock, 2016), device aesthetics (Dos Santos et al., 2022), the social perception of assistive tools (Nierling & Maia, 2020), and the emotional experience of interaction (Desmet, 2012) directly affect perceived dignity, hedonic quality, and overall acceptability (Siedl & Mara, 2021; Elprama et al., 2022; Gutierrez et al., 2024; Dufraisse et al., 2025). These contributions show that without careful attention to emotional dimensions, even technologically advanced solutions risk being rejected, abandoned, or perceived as stigmatizing. Within this context, the field of assistive exoskeletons remains largely unexplored from an emotional perspective, despite the intimate and prolonged contact between body, machine, and relational environment making such analysis indispensable. An exoskeleton is not merely a mechanical device that redistributes loads and supports complex postures—it is a wearable artifact that intervenes in the operator's physical presence, self-perception, and direct interaction with patients. Understanding how these aspects shape feelings of competence, trust, comfort, and control is essential for designing technologies that are not perceived as intrusive or stigmatizing, but rather as familiar, reassuring, and pleasant to wear. Incorporating an emotional perspective means designing devices that are not only functional, but also capable of being worn naturally, comfortably, and with a sense of empowerment—a necessary condition for these technologies to become a genuine part of healthcare workers' daily routines. The study described in this paper focuses on emotional aspects and was conducted as part of the Exo.Care research program, funded by the Tuscany region. The research program involves a partnership consisting of three research organizations, two social cooperatives, and two metalworking companies. The overall objective of the research is to develop and test an innovative passive exoskeleton designed to support nursing activities and hygiene practices for people living in residential care facilities for the elderly (RSA), as well as patients living in their own homes. This study analyses the

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role of ergonomics in design as a methodological framework for identifying and evaluating the emotional factors that positively or negatively influence the acceptability, hedonic quality and usability of exoskeletal devices. From a Design for All perspective, the ergonomic approach supports the design of inclusion solutions able of responding to the variability of users and application contexts in the healthcare sector. The systematic integration of ergonomic and emotional aspects into design process contributes to the development of exoskeletons that not only meet functional and safety requirements but also improve the overall user experience and adoption of the device over time. Finally, the manuscript contributes to bridging the scientific gap in design research and industrial product design by providing qualitative data for a sector that is in its infancy but has excellent potential for future development.

METHODOLOGY

Thanks to Ergonomics for design and, more specifically, to the Human-Centered Design approach and its methodological framework, several methods were selected that enabled the research team to explore the main problems, primary and secondary needs, and, eventually, the desires experienced by those providing healthcare assistance both in nursing homes and in home-care settings. The methodology used to conduct the study on the analysis of healthcare workers is part of Ergonomics research applied to design. The study adopted a mixed-methods approach that combines qualitative and quantitative methods. It investigated the perception of pleasantness, emotion, usability, and user experience, as well as the physical workload required of social and healthcare operators during personal care activities. More specifically, the following methods were used Geneva Emotion Wheel (GEW) and User Experience Questionnaire (UEQ). The GEW Protocol (Geneva Emotion Wheel) is a metric proposed by Scherer (2005), based on a systematic circular model used to measure individuals' emotions during an activity. It is structured on a Cartesian plane, systematically organized into two dimensions: on the horizontal axis, it indicates valence (negative and positive), and on the vertical axis, it represents activation (high and low), dividing emotions into four quadrants, as recommended by Sacharin et al. (2012). The protocol used is presented in version 2.0 in a circular format and is composed of 20 emotional reactions (10 positive and 10 negative). For each emotion, a five-anchor radial scale is provided, varying emotional intensity according to the size displayed (small: low intensity; large: high intensity). At the center, there are the options "no emotion" and "other emotion," which allow the participant to describe the emotion they are feeling and the perceived intensity, in accordance with the principles established by Scherer et al. (2013). The effectiveness of the GEW method has been demonstrated in scientific studies (Desmet and Schifferstein, 2012; Alaniz and Biazzo, 2019; Coyne et al., 2020), which confirm that emotional evaluation can positively influence the process of generating new product ideas. Meanwhile, the User Experience Questionnaire (UEQ) made it possible to evaluate the user experience of healthcare professionals after using the exoskeleton. At the end of the 30-day experimentation period, each operator was asked to complete the UEQ questionnaire. User Experience (UX) refers to the set of emotions, perceptions, and reactions that a person experiences when interacting with a product or service. In other words, it corresponds to the subjective degree of alignment between expectations and satisfaction during interaction with a system, whether physical or digital. UX is therefore a design dimension that places users' characteristics and needs at the center, focusing on the entirety of experiences within a specific context of use. The UEQ consists of 26 items, each representing a semantic differential in which every item is composed of two

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terms with opposite meanings (Laugwitz et al., 2009; UEQ-Online). The order of these terms is randomized for each item; more specifically, half of the items begin with the positive term, while the other half begin with the negative term. To quantify user experience, the UEQ employs a 7-point Likert scale, where −3 represents the most negative response (value 1/7 on the Likert scale), 0 represents a neutral response (value 4 on the Likert scale), and +3 represents the most positive response (value 7/7 on the Likert scale). The effectiveness of the method has been tested in international studies (Schrepp et al., 2014; Lappalainen et al., 2016; Rauschenberger et al., 2013), which have shown how the User Experience Questionnaire (UEQ) can reveal a series of quantitative data that will allow researchers and designers to make assumptions about possible areas for future improvement of the product being analyzed. The UEQ is structured into six scales comprising 26 items, as follows:

- Attractiveness: overall impression of the product. Do users like or dislike the product?
- Perspicuity: Is it easy to become familiar with the product? Is it easy to learn how to use it?
- Efficiency: Can users complete their tasks without unnecessary effort?
- Dependability: Does the user feel in control of the interaction?
- Stimulation: Is it exciting and motivating to use the product?
- Novelty: Is the product innovative and creative? Does it capture users' attention?

Attractiveness represents a pure valence dimension, whereas Perspicuity, Efficiency, and Dependability correspond to pragmatic quality aspects (goal-oriented). Stimulation and Novelty, in contrast, correspond to hedonic quality aspects (non-goal-oriented). The Attractiveness scale contains six items, while all other scales contain four items each.

Figure 1. Simulated patient handling tests conducted by healthcare workers (OSS) while wearing the passive exoskeleton in a controlled real-world environment. Task: lifting and moving a patient from one seat to another.

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For the needs analysis, and in agreement with both the wearable robotics company and the social cooperatives, it was decided to leave the exoskeleton for a 30-day trial period. The participants selected by the facility managers who wore the exoskeleton completed the Geneva Emotion Wheel (GEW) twice. The first GEW completion took place after observing the exoskeleton (T0). The second occurred after testing the exoskeleton at the end of the 30 days (T30), each participant completed the UEQ questionnaire at T30. Regarding the users, four social and healthcare workers (3 women and 1 man) of varying ages and experience levels were involved in the study (see Table 1). Their tasks include assisting, moving, caring for, and providing hygiene support to older adults. Within this context, the type of older adults who benefit from this care service is heterogeneous: some are cooperative and cognitively active, while others are uncooperative and cognitively passive. This condition affects the quality of the service provided, as well as the need for one or more social and healthcare workers.

User	Nursing home	Service	Gender	Age	Employment	Nationality
1	Uscita di sicurezza - Orbetello (Grosseto)	Healthcare assistance in RSA	F	47	OSS	Italian
2	Uscita di sicurezza - Orbetello (Grosseto)	Healthcare assistance in RSA	F	56		
3	NOMOS, cooperativa sociale (Firenze)	Home healthcare assistance for the patient	F	37		
4	NOMOS, cooperativa sociale (Firenze)	Home healthcare assistance for the patient	M	48		

Table 1. Meta-data of participants involved in the study.

RESULTS

Below are the GEW findings that emerged from the experimentation. With regard to the GEW, the results indicate that at (T0), after a moment of familiarization and trust-building with the exoskeleton, participants were asked to complete the GEW. In this phase, the emotions expressed by the four participants were mostly positive. We believe this result is related to the potential offered by wearable technology. It is important to note that not all emotions were positive; in fact, two participants reported negative emotions such as shame and fear. The following graph shows the trend and intensity of the emotions experienced by the four operators before using the exoskeleton. GEW after use (T30): After the 30-day period, participants were reassessed regarding their emotional perception of the exoskeleton usage experience. The results indicate a decrease in the intensity of positive emotional responses following familiarization with the technology. The interest factor decreased (T0 average: 5.0 / s.d.: 0 to T30 average: 3.5 / s.d.: 2.38), as did amusement (T0 average: 2.25 / s.d.: 2.63 to T30 average: 0.75 / s.d.: 1.5), contentment (T0 average: 1.75 / s.d.: 2.06 to T30 average: 1.0 / s.d.: 2.0), and admiration (T0 average: 2.0 / s.d.: 2.45 to T30 average: 0.75 / s.d.: 1.5). Perceptions of fear (T0 average: 1.25 / s.d.: 1.5 to T30 average: 1.25 / s.d.: 1.5) and pleasure (T0 average: 1.25 / s.d.: 2.5 to T30 average: 1.25 / s.d.: 2.5) remained at the same low intensity after the usage period. The shame factor decreased (T0 average: 0.75 / s.d.: 1.5 to T30 average: 0 / s.d.: 0), which may indicate greater acceptability of the technology with continued use and learning. Additionally, disappointment (T0 average: 0 / s.d.: 0 to T30 average: 0.25 / s.d.: 0.5) and relief (T0 average: 0 / s.d.: 0 to T30 average: 1.0 / s.d.: 2.0), which were not reported at T0, were identified at T30.

Iacono, E., Porsani Nucci, R., Pistolesi, M. (2025). Emotional experience and acceptance of passive exoskeletons in healthcare sector: insights from a human-centered design approach. *Rivista Italiana Di Ergonomia*. 31. 52-62. DOI: 10.6093/RIE/13408

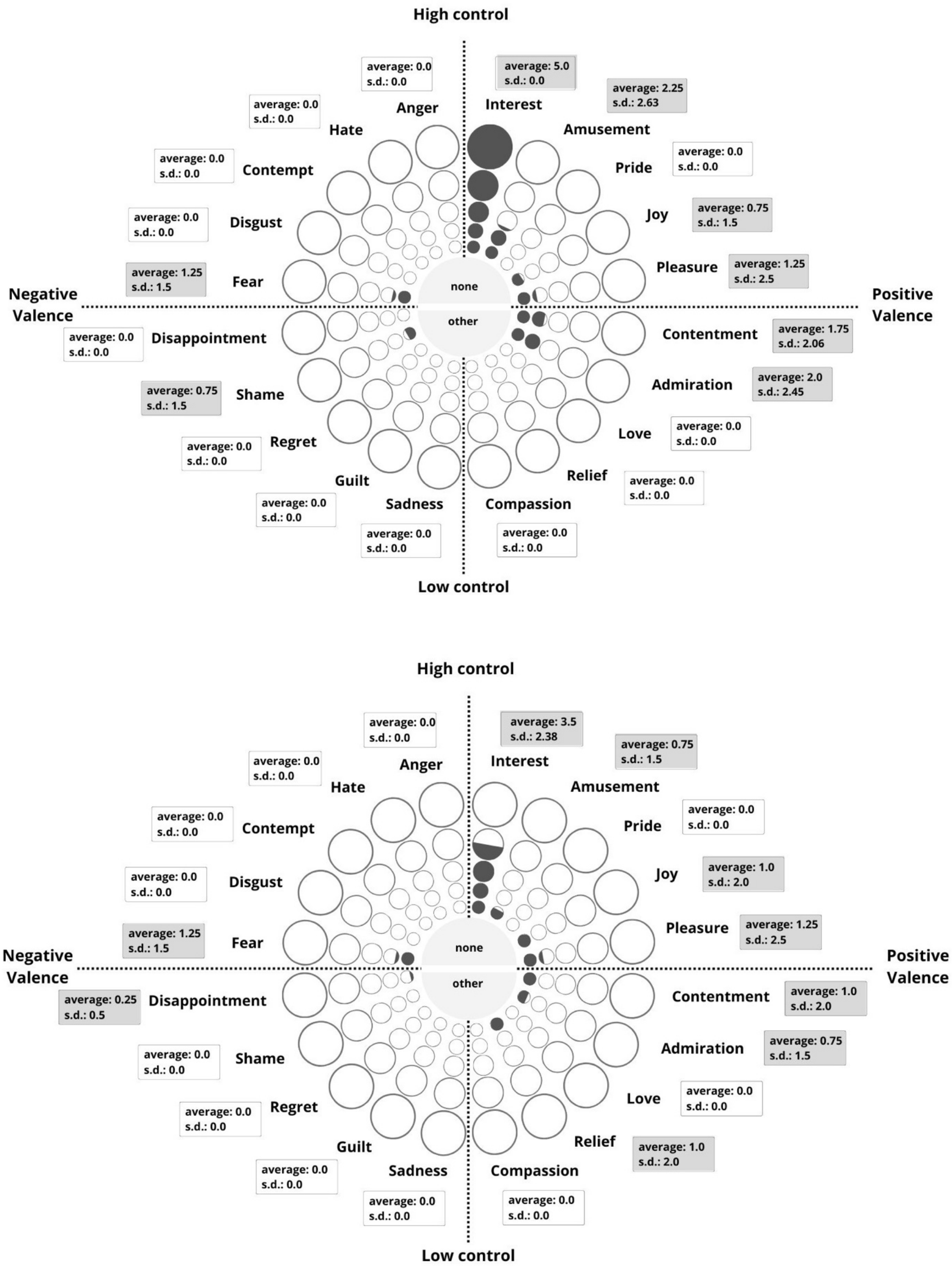

Figure 2. T0 (top) and T30 (bottom) GEW Results

In summary, after the 30-day period, a significant reduction in the intensity of reported positive emotions was observed (particularly interest, amusement, contentment, and admiration), which may be related to the process of familiarization and acceptance of the technology. Additionally, only two negative emotional indications were maintained at T30: fear, which may be associated with usability factors and potential injury risks for both the OSS user and the patient, and disappointment, which, although low in intensity, may reflect some level of frustration regarding the user's prior expectations of the equipment. Thanks to the UEQ questionnaire, it was possible to collect a considerable amount of data. For this reason, only the most relevant results are reported below and presented together. The standard interpretation of the scale highlights that values between −0.8 and 0.8 represent a neutral assessment of the UX, while values > 0.8 indicate a positive evaluation. Conversely, values < −0.8 indicate a negative evaluation. Finally, the value −3 represents an extremely poor rating, whereas the value 3 represents an extremely good one (UEQ Online). As evidenced in Figure 3, the individual

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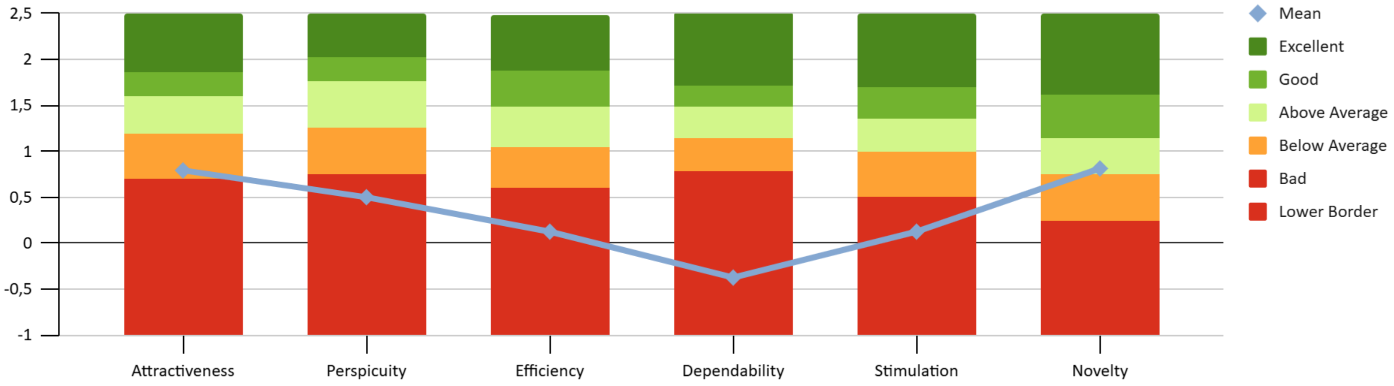
scales indicate a User Experience (UX) with the exoskeleton that tends toward neutral to negative. The lowest results correspond to three fundamental aspects of exoskeleton technology, efficiency (n = 0.13), stimulation (n = 0.13) and dependability (n = −0.38). The reasons underlying these scores have already been extensively discussed in the previous sections. An interesting finding, as anticipated, concerns the aspects of novelty (n = 0.81) and attractiveness (n = 0.79), whose values are to be considered positive.



Mean	Comparisson to benchmark	Interpretation
0,79	**Below average**	50% of results better, 25% of results worse
0,50	**Bad**	In the range of the 25% worst results
0,13	**Bad**	In the range of the 25% worst results
-0,38	**Bad**	In the range of the 25% worst results
0,13	**Bad**	In the range of the 25% worst results
0,81	**Above Average**	25% of results better, 50% of results worse

Figure 3. UEQ Results.

The analysis of the User Experience Questionnaire (UEQ) results indicates that the overall experience with the exoskeleton tends toward a neutral-to-negative evaluation across most of its dimensions. The scales related to Perspicuity, Efficiency, Dependability, and Stimulation fall within the range of the 25% worst results in the UEQ, revealing difficulties in learning to operate the device, low operational efficiency, a reduced sense of control during use, and limited motivational engagement. Attractiveness obtained a slightly below-average score, suggesting moderate acceptance but limited overall satisfaction. In contrast, Novelty was the only positively rated dimension, classified as above average, indicating that the exoskeleton is perceived as innovative and capable of capturing users' interest. Overall, the findings suggest that although the technology is recognized as original and somewhat appealing, significant usability challenges remain, particularly concerning ease of learning, operational performance, and perceived control, highlighting the need for improvements in ergonomic design, interaction quality, and training support.

CONCLUSIONS AND FINAL CONSIDERATIONS

The results of this study offer an initial understanding of the emotional dynamics and user experience associated with the use of a passive exoskeleton by healthcare workers in a care setting. The adoption of wearable technologies in the healthcare sector, while showing significant potential for improving the physical well-being of workers and reducing the biomechanical load during handling activities, is accompanied by a series of psychological and usability implications that deserve attention. Emotion analysis using the Geneva Emotion Wheel (GEW) showed that initial contact with the exoskeleton

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generated predominantly positive emotions, such as interest, admiration, and curiosity. This is consistent with the 'novelty' effect typical of emerging technologies, which tends to generate high expectations and initially favorable perceptions. However, not all reactions were positive: the presence of emotions such as fear and shame indicate that the introduction of visible, mechanized body devices can also influence aspects related to self-perception, professional image, and perceived safety. After 30 days of use, the intensity of positive emotions decreases significantly. This phenomenon suggests a process of normalization and familiarization with the technology, but also a possible gap between initial expectations and actual perceived and experienced performance. The emergence of feelings such as disappointment and relief indicate a more pragmatic reflection on the real impact of the exoskeleton on daily work activities. At the same time, the results of the User Experience Questionnaire (UEQ) confirm significant operational difficulties. The aspects with the lowest scores—efficiency, stimulation, and reliability—show that the exoskeleton was not perceived as an immediately useful, easy-to-integrate, or particularly motivating tool. The critical issues identified could be related to the perceived weight of the device, its adjustment methods, the adaptation time required, and potential interference with the established routine of healthcare assistants during care activities. Despite this, the novelty and attractiveness of the device support the perception that it has significant potential and represents an innovative solution in the healthcare sector. This result reaffirms the interest of operators in technologies that can reduce physical strain and increase safety at work, provided that they are truly human-centered, intuitive, and integrated into work processes. It should also be emphasized that the emotional dimension plays a primary role in the acceptability of wearable technologies. Negative emotions such as fear or discomfort can be an obstacle to adoption, while good user-centered design can help minimize these effects and promote the integration of the device into care practices. From a methodological point of view, this study confirms the importance of a human-centered approach and the combination of qualitative and quantitative tools to understand not only the technical functioning of technologies but also the emotional and perceptual experience of operators. In conclusion, the research experience presented emphasizes that, although the exoskeleton is perceived as an innovative and potentially useful device, its perceived effectiveness and level of usability are still limited in the real work context. The main findings suggest that:

- The initial emotional impact is strongly positive, but tends to diminish over time, highlighting the need to improve consistency between expectations and actual performance.
- Some negative emotions persist, such as fear, related to safety factors, perceived risk, and complexity of use.
- The overall user experience tends to be neutral or negative, especially in relation to pragmatic aspects such as efficiency, comprehensibility, and sense of control.
- The perception of novelty remains high, indicating that the technology is seen as promising and arouses interest, but requires significant improvements to become truly integrable into care practices.
- Overall, the results indicate that the introduction of exoskeletons in the care sector must be accompanied by:
- more refined ergonomic design in line with the real needs of potential end users, focusing on differences in physical abilities, age, gender body type and work experience among healthcare workers;
- ergonomic design that takes into account different contest of use such as nursing homes and homes of older people;

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- adequate and personalized training of staff aimed at raising awareness of the future use of exoskeletons in the healthcare context;
- gradual adaptation processes necessary to satisfy the technology-human-environment relationship.

Only through improved usability and constant support for operators will it be possible to transform initial interest into stable and informed adoption, with concrete effects on reducing physical strain, increasing safety, and improving well-being in the workplace. In conclusion, the integration of ergonomics, HCD and Design for all plays a crucial role in identifying and analysing often unexpressed needs in order to create people-centred products and understand the changes hat ageing brings to daily routines, usage patterns, attitude and perceptions of products.

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SHORT BIO

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