# Exoskeletons - Human-Centred Solutions to Support Care Workers?

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# 1. Exoskeletons – human-centred solutions to support care workers?

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## Abstract

Care work involves various physically strenuous stages. Tools of different kinds, such as cranes, can be used to facilitate the work, but if no suitable tool exists, the care worker's physical strength is used as an aid. This can easily lead to injuries, sick leaves, and early exits from work life. Exoskeletons, a form of wearable robotics, can support care workers by reducing physical exertion and supporting posture and motion. They are being used in other fields, such as industry, with good results, but little is currently known about the use of exoskeletons to support care work. Integrating technology into care work is a question of mutual adjustments between technologies and various work practices. In this chapter, we examine – from the point of view of technology domestication – the implementation and use of exoskeletons in care services. We make use of a field study of user experiences with the Auxivo LiftSuit exoskeleton in elderly care that was conducted in two care homes in Finland. Both factors that support domestication and those that delay it are presented, resulting in new knowledge concerning the exoskeleton in question and the more general prerequisites for domestication of exoskeletons in care work. These findings may be utilised to develop future domestication processes, thus advancing human-centred service design in care services.

## 1.1 Introduction

Care work involves many kinds of physically strenuous stages. Physical work stages can be facilitated by various tools, like cranes; there is naturally no suitable tool for every stage of multi-faceted care work. The caregiver's physical strength is traditionally used as an aid, which can easily lead to injuries, sick leaves, and early exits (Davis & Kotowski, 2015; Trydegård, 2012). In light of this, changes to Finland's population structure, especially regarding the dependency ratio, which is at its highest value in sixty years (Kalluinen, 2018, p. 1), have been worrying. An increased dependency ratio means, among other things, that the number of care workers decreases in proportion to the growing number of people who require care (United Nations, 2007, p. 104). The same phenomenon has been observed elsewhere in the world (Skirbekk et al., 2022, p. e332). Concerns have thus arisen regarding this growing shortage of care workers. In the current era of healthcare transformation, exoskeletons, a form of wearable robotics, have been introduced as a way to support care workers by reducing their physical exertion.

According to ASTM International (2021, p. 2), an exoskeleton is "a wearable device that augments, enables, assists, and/or enhances physical activity through mechanical interaction with the body." According to the same standard, an exoskeleton may include rigid or soft components, or both, and the physical activity may be static or dynamic. For this reason, exoskeletons can be classified as active or passive (de Looze et al., 2015, p. 671). Active exoskeletons use actuators, such as electric motors, that increase the human's power and reinforce their joints. Passive exoskeletons do not use actuators but instead use materials, such as springs, which store the energy harvested by human motion and then use that energy to support the user's posture or motion. Exoskeletons have been deployed in other fields, such as industry, with good results (de Looze et al., 2015, p. 671).

A review of the scientific literature reveals a research gap concerning the implementation of exoskeletons in care work; further research is needed to ensure that the related service design is human-centred. It is also necessary to clarify whether there are indeed exoskeletons that are suitable for care work and how they should be implemented. The implementation of exoskeletons could potentially prolong the careers of nurses and increase the number of active care work professionals in the future. However, the field of social and health care services is challenging and complex, and it is therefore necessary to think carefully about how to bring new tools to care work and precisely what tools are needed.

The aim of this research is to examine – from the point of view of technology domestication – the implementation and use of exoskeletons in the field of social and health care services. This is done with the help of a field study concerning user experiences with the Auxivo LiftSuit exoskeleton (referred to as "suit" or "device" hereafter) in elderly care that was conducted in two care homes in Finland. The research questions are: (1) How are exoskeletons implemented and used in the field of social and health care services? (2) What are the user experiences of exoskeletons in care work? and (3) What are the central prerequisites for domestication of exoskeletons in care work? This research makes several contributions. By examining implementation and use via a field study, both factors that support domestication and those that hinder it are highlighted, resulting in new knowledge concerning the exoskeleton in question as well as the general prerequisites for domestication of exoskeletons in care work. With the help of our findings, future domestication processes will likely be developed, leading to advances in human-centred service design in care services.

## 1.2 Background

This section discusses definitions and characteristics of robots in care and the concept, process, and dimensions of technology domestication. Four dimensions of technology domestication are evaluated in this research.

### 1.2.1 Robots in care

Care robots are defined as partly or fully autonomous machines that perform care-related activities for people with physical or mental disabilities related to age or health restrictions (Goeldner et al., 2015, p. 115). Care robots may also assist care workers, for example assistant nurses, in their daily tasks (Melkas et al., 2020, p. 4-5; Tuisku et al., 2022, p. 1-2), allowing more time to perform those tasks that require human touch (Bush, 2001, p. 256). Wu et al. (2012, p. 121) divided such robots into monitoring robots (to observe behaviour and health), assistive robots (to provide support to the individual or their caregiver in daily tasks), and socially assistive robots (to provide companionship).

Niemelä et al. (2021, p. 12-13) classified robotic applications and services according to their use contexts and purposes, differentiating between robots created to (a) maintain the independence and participation of an older adult, (b) improve the efficiency and ergonomics of the care worker, (c) improve recreation and non-physical rehabilitation and therapy, (d) automate secondary tasks in care, (e) improve physical rehabilitation therapy and experience, (f) support manual work (e.g., in terms of precision or heavy lifting), and (g) support logistics and safety in hospitals. Examples of these robots are telepresence robots (e.g., Double and Giraff), medicine-dispensing robots (e.g., Evondos), robotic walking aids (e.g., Lea), robotic spoons (e.g., Gyenno), exoskeletons for the rehabilitation of the patient (e.g., Indego) or for supporting the care worker (e.g., Laevo, Auxivo), transportation robots for delivering meals and medicine (e.g., TUG), and social robots for therapy, entertainment, and communication (e.g., Paro, JustoCat, Zora, & Pepper; Niemelä et al., 2021, p. 12-13).

In several studies, attitudes toward robots in care are found to be more negative than in many other occupational fields, including education, business, and industry (European Commission, 2012, p. 4-5; 2015, p. 58; Taipale et al., 2015, p. 18). The general public's attitudes toward the use of robots in the care of older people were also examined in a media analysis that showed that opinions were mostly negative (Tuisku et al., 2019, p. 61-63). These results may be explained by the fact that people consider it inhumane for a robot to take care of a person; the main concern was that robots would replace human-to-human contact and care. However, Broadbent et al. (2010, p. 608) found that participants could identify many benefits and applications for healthcare robots, including performing simple medical procedures and providing physical assistance. Turja et al. (2018, p. 304-305) investigated the attitudes of Finnish healthcare workers toward the use of robots in welfare services and discovered that their views were generally negative. However, the healthcare workers did consider a robot to be acceptable for certain work tasks, such as heavy lifting. So, attitudes toward robots depend upon the specific robot and task in question. A lack of knowledge related to robots may lead to false impressions concerning robots' capabilities and the associated risks, thus leading to negative attitudes (Johansson-Pajala et al., 2019, p. 220-223; Tuisku et al., 2019, p. 64). The provision of hands-on experience and promotion of increased awareness and education about what care robots can do are both necessary to moving away from preconceptions based on fiction and imaginary images of robots (Frennert et al., 2021, 322). Studies have indicated that prior exposure to robots – when people were given more knowledge about robots, were shown a robot, or were able to use one – positively affects attitudes toward them (Broadbent et al., 2010, p. 612; Johansson-Pajala et al., 2019, p. 222; Melkas et al., 2020, p. 5).

### 1.2.2 Technology domestication

Technology domestication theory (Haddon, 2011; Sørensen, 2005; Silverstone & Haddon, 1996) describes the unlinear processes that occur between people and technologies when users "tame" technologies and integrate them into their everyday lives (Hargreaves et al., 2018, p. 129). The concept has its roots in the 1990s, when there was a holistic view of ICT use in homes (Haddon, 2006, p. 195) and in media studies (e.g., Silverstone et al., 2003 and Silverstone & Haddon, 1996, see also Hartmann, 2020, p. 47), but it has grown to include study of the adoption of specific technologies as well, such as cable TV (Haddon, 2011, p.  316-317), mobile phones (Haddon, 2003), and cars (Sørensen, 2005; see also Haddon, 2006, 2011). The framework considers the processes that shape the adoption and use of ICTs; in so doing, it also asks what the technologies and services mean to people, how they experience them, and what roles these technologies come to play in their lives (Haddon, 2011, p. 312).

Domestication theory emerged in response to the classic idea of diffusion of innovations (Rogers, 1983), which views technologies as pregiven, unchanging entities that diffuse through society in a linear way, implying an extremely passive role regarding the user, who simply adapts what is offered to them, little by little, in one social stratum after another (Hargreaves et al., 2018, p. 129; Lehtonen, 2003, p. 364). Innovation is not only a matter of production but one of consumption and use, which are essential components of the innovation process (Silverstone & Haddon, 1996, p. 44). Thus, regarding innovation processes, domestication represents the user side of innovation: domestication is anticipated in design, and design is completed in domestication (Silverstone & Haddon, 1996, p. 46). This is linked to an idea from the STS (science and technology studies) literature that views technologies as being "scripted" by technology designers, meaning that the technology itself gives hints about how technology will function and how it should be used. Technology also makes assumptions regarding users' needs and the related contexts (Akrich, 1992, p. 208-209; Stokke, 2017, p. 3), with which users may align or dissent. Likewise, when technology is domesticated, users can follow or disregard these initial scripts. Users are not passive adaptors of technologies but rather give meaning to them, and technology addresses users in specific, targeted ways.

The domestication perspective highlights that technologies are not fixed entities; they acquire specific forms of use and meanings when they are adopted and embedded in a given locality (Ingeborgrud & Ryghaug, 2019, p. 510; Silverstone et al., 2003, p. 13-28). This perspective does not only focus on how technologies are "accepted" through practical use but also on how people learn to use a new technology and, not least, on the symbolic values and meaning creation central to the adoption process. In the process of domestication, users make technology meaningful in their lives (Pols & Willems, 2011, p. 485). Technology domestication aims to open the "black boxes" in technology use and reveal the processes and practical, symbolic, and cognitive negotiations that occur when technology is integrated into use (Aune, 2002, p. 5). These processes include technology producers, users, managers and decision makers, and the technology itself. Through these processes, technology and people shape each other: the technology has an impact on users, for instance by changing their practices, and the users have an impact on the technology.

Technology domestication is not a one-off event but a process that includes the effort invested before acquisition to imagine how technology might find a place in people's lives (Haddon, 2006, p. 2). Domestication mainly focuses on three generic feature sets (Sørensen et al., 2005, p. 47):

1) The construction of a set of practices related to an artifact. This might include the routines

related to using the artifact as well as the establishment and development of institutions to support and regulate this use;
2) The construction of the meaning of the artifact, including the role the artifact could eventually play in relation to the production of the identities of the actors involved; and
3) The cognitive processes related to learning the practices and meaning.

In other words, the *practical dimension* concerns the ways in which users integrate the technology into already existing routines and how they establish new routines through use; the *symbolic dimension* refers to the ways in which users attach meanings to a new piece of technology, including self-representation, by means of using the technology; and the *cognitive dimension* refers to how people learn to use new technologies. These three dimensions are overlapping. When people domesticate technology, they fit it into their routines, place it, give it meaning, and learn to use it, or they abandon it (Aune, 2002, p. 5). Thus, domestication theory addresses both questions of use and of nonuse with a holistic view of people's circumstances (Haddon, 2011, p. 319-320).

Søraa et al. (2021, p. 8) suggested that the *social dimension* should also be added to the domestication theory and highlighted the social processes involved in technology domestication. In these processes, technology can be seen as an actor that impacts the interaction between people and is coproduced, not only by the individual but by a wide variety of actors (Søraa et al., 2021, p. 11). The social dimension is therefore included in this study.

Most prior domestication studies have concentrated on the micro level (individuals and households), so less attention has been given to life outside the home (Haddon, 2011, p. 315; Pierson, 2006, p. 206); however, some recent studies have also considered societal-level domestication (Morley, 2005; Sørensen, 2005 see also Haddon, 2011). In this study, we evaluate technology domestication in a specifically organisational and work environment context (see Peine & Herrman, 2012 Pierson, 2006) but this context also speaks to the suitability of exoskeletons in the care field more widely.

## 1.3 The field study

The basics of the field study are described in this section. We introduce the tested exoskeleton and explain the data collection and analysis.

### 1.3.1 The tested exoskeleton

Auxivo LiftSuit® (see figure 1 and figure 2) is a Swiss passive exoskeleton that supports the back when lifting objects below waist level or when working in a forward leaning position. Textile springs on the back store energy, which is released when used to support the user's movements. The support is activated and deactivated by the straps in the front. The suit comes in two basic sizes but is designed to further adapt to wearers of different sizes via an adjustment mechanism. The suit can be washed in the washing machine at 30 °C and wiped with disinfectants. Safety loops, that is, rubber bands that can attach to the straps of the adjustment mechanisms in order to avoid leaving them hanging, help to ensure safety during use (Auxivo AG, 2022).

Fig. 1 Auxivo LiftSuit®, Source: Riika Saurio (2022).

### 1.3.2 Data collection and analysis

The research environment was a care home called Pohjola, which is located in and run by the city of Tampere, Finland. Pohjola offers round-the-clock housing services for older persons. Eight assistant nurses, recruited on a voluntary basis, took part in the field study. They were 19–61 years old, and their working experience in the care sector ranged from 1.5 years to 40 years. The participants were divided into two groups, and each participant was able to use an Auxivo LiftSuit exoskeleton for three weeks (four assistant nurses at any given time).

This study uses qualitative data that were collected through pre-interviews and post-interviews as well as user diaries written during the trial. This research is part of the TUEKS project, "Exoskeletons and caregivers' changing daily work", supported by the Finnish Work Environment Fund (in addition to the qualitative data presented here, quantitative data were collected via physiological measurements by the Finnish Institute of Occupational Health). During the day of the pre-interviews, the participants received a comprehensive orientation and introduction to the use of the device from a researcher who also has a background in nursing. The number of participants was considered adequate for the nature of the research (see Turja et al., 2020, p. 13). The interview questions concerned expectations for and experiences of the use of the device, its experienced impacts on work, orientation needs, and other people's reactions toward use of the device. The user diary collected information on immediate experiences and the purposes and times of use.

The qualitative data were analysed with the help of content analysis and data categorisation. In the analysis, there were both inductive and deductive phases. After data transcription, the data were reduced into essential contents and then inductively coded using an interpretive approach that involved searching for recurrent themes and naming them. Subsequently, the themes were deductively categorised into the four dimensions of domestication theory (practical, symbolic, cognitive, and social). The findings, organised by dimension, are presented below. At a later stage, an implementation model for exoskeletons will be developed and piloted by the researchers. This model will utilise domestication theory and focus on what implementation requires from the nursing staff, organisation, and managers.

## 1.4 Findings

The findings concerning practical, symbolic, cognitive and social domestication of the exoskeleton are presented in this section. Descriptive quotations are given where appropriate.

### 1.4.1 Practical domestication of the exoskeleton

When studying the practical dimension of domestication, we need to examine the ways in which users integrate the technology into already existing routines and establish new routines through use (Ingeborgrud & Ryghaug, 2019, p. 510), as well as the construction of a set of practices related to the artifact. This could mean the routines involved in using the artifact but also the establishment and development of institutions to support and regulate this use.

According to our field study results, the practical domestication-related issues – the ways in which users integrate the technology into already existing routines and create new routines through the technology use – were related to, for example, practicalities concerning work tasks and storage locations of the exoskeleton. The device was felt to be most practical for bed care activities, such as bed washing and changing diapers. During showering days, it was useful for helping the resident to the showering platform and doing the showering in the sauna facilities.

> *"For evening wash and posture shifting, and for assisting residents in wheelchairs to the toilet and from there to bed. And evening activities […] I used it when there was feeding and during mealtimes […] that's when I tried to wear it quite a lot."*

The starting point for the trial was that the device could be used in all work tasks, and therefore, during the field study, use of the device did not necessitate any extra planning. However, once the most suitable tasks were identified during the field study, it was noted that proper planning would definitely be needed for regular use of the device. The participants wished that they could reserve the suit for a showering day, for instance.

> *"… About the planning, well, I didn't really plan it. I thought I'd wear it and let's see…"*

Practical issues considered to be challenging included tasks that had to be done in a squatting position (such as assisting during toileting), as the exoskeleton felt tight or compressing during those times, especially on the thighs and shoulders. During showering tasks, it felt sweaty. A few other details were also brought up:

> *"…the straps […] you always had to adjust those, and sometimes it happened that they got tangled in the edges of the bed. […] We work inside, and it can be hot sometimes. When you think that we would use it in the summer, it's really hot, sweaty."*

Participants also mentioned that the device is not able to be used by diverse body types. On the other hand, one interviewee mentioned:

> *"It kept the posture perhaps a bit better. It makes you automatically straighten up, I had that feeling. So it helped in having a better posture, as you tend to stoop anyway, so that was a good thing."*

The participants thought that it was practical that the exoskeleton was unobtrusive; as a result, the residents did not pay much attention to it. The caregivers usually wore blue workwear, and they felt that the LiftSuit did not stand out.

As a prerequisite for use, it was necessary that the device be visible and available in the workplace, which ensured that care workers remembered to use it. A good place for storage was found to be the door stoppers on the doors, where the exoskeletons could hang freely (see figure 3). The interviewees mentioned that if exoskeletons were stored in lockers, for instance, their use would be less convenient. The participants also noted that the skills related to using the device had to be mastered before adjusting it to the user's specifications became an easy task.

Hygiene – how the exoskeleton would be washed or disinfected – was seen as a practical challenge that also affected the domestication process. The exoskeleton is washable, but could it be washed together with other laundry (e.g., residents' clothes)? Should it be washed separately, even in a separate washing machine? Could it be used by several nurses before it needed to be washed?

> *"… That it would be visible so that you would in general remember that [the exoskeleton] exists and we can use it… and of course, the hygiene; how it could be used by many of us and so forth…"*


Fig. 3 A handy place for storage, Source: Satu Pekkarinen (2022).

### 1.4.2 Symbolic domestication

The symbolic dimension of domestication refers to the ways in which users attach meanings to a new technology (Ingeborgrud & Ryghaug, 2019, p. 510). The construction of the meaning of an artifact, including the role that the artifact could eventually play in relation to the production of the identities of the actors involved, is examined in this section.

According to our results, the suit was typically considered by participants to be a normal or traditional work assistive device and had no specific connotations. However, some caregivers interestingly called it by Finnish male names: "Esko" and "Eki."

One of the participants experienced the use of the exoskeleton as an extra burden. When the participant could take the suit off, it was a relief. Another participant, who was over 50 years old, felt that the suit would be more suitable for younger care workers, as the skin and the body become less flexible as one ages, making the suit uncomfortable:

> *"…in the final stage I felt it was a bit burdensome to use it, it somehow felt a bit distressing to wear it [a laugh]."*

Some of the participants noted that simply bringing up nurses' need for help in their physically burdening work and showing that technology like this can be developed for them carries significant symbolic societal value. This is important in comparison with other fields of services and in relation to the service clients. The interviewees emphasised that, in general, there is great need in an ageing society to develop solutions and work practices that enable nurses to cope with their work.

*"And it is also that the voice of the nurses comes out, nurses' wellbeing is considered […] There is also that aspect, in my view. A kind of societal call from there – that nurses also need something […] some help."*

*"…the principle is really good in that [work] is aimed to be developed with the help of technology, or with the help of anything, because this is so heavy work. […] I haven't, fortunately, had to see anymore the beds without wheels and how nurses carried them. We have come from there, which is pretty staggering; the development of ergonomics during the last decades."*

### 1.4.3 Cognitive domestication

The cognitive dimension of domestication is related to cognitive processes that concern the learning of practices and meaning. The cognitive dimension thus refers to how people learn to use new technologies (Ingeborgrud & Ryghaug, 2019, p. 510).

According to our results, after pre-adjusting the suit, taking it on and off was generally felt to be easy. Some of the participants had challenges in putting on the thigh parts because of difficulties related to finding the right strap. The plastic parts were also felt to be somewhat challenging, as they were slippery. Two participants expressed a wish for a rougher material or for a ball- or T-shaped strap for the activating straps. The suit itself was felt to be easy to use, but there were issues concerning comfort of use.

The most challenging issue was remembering to activate and de-activate the suit. One participant, for instance, completely forgot to activate it during a work task. Reminders and getting properly used to the suit will help to overcome this obstacle.

*"Well, it was easy to put it on. […] But you have to remember to activate the suit before you do some task, it was a bit … in the beginning I hardly remembered to take care of activating and did the work without it."*

The orientation focused on the use of the device was given in a slideshow format, and it described the purpose of the suit and possible barriers to use. Instructions for putting on the suit were presented in a video. Each participant then received individual assistance in putting on the suit and taking it off. In addition, there was a lifting exercise in which the participants lifted a chair with and without activation of the suit. This exercise demonstrated the powerful support that could be expected from the device. Finally, the participants received an instruction manual in their native language and the phone number of a researcher they could call if they experienced any problems. These were seen as good practices by the participants.

*"It is a certain type of a device that you need … that people understand what this is all about. And then, how it is used and why […] I think that all these became clear. There was also enough written material and you had the videos […] so I think that they were clear and I don't believe that you could have presented it in any better way."*

> *“The instructor’s own nursing background was a nice addition, I think it showed that the instructor has a good perspective to the use. [The instructor] should always understand what kind of work we are doing here, and that should be the starting point for the instructor, whoever it is.”*

Considering cognitive domestication, practical issues were most appreciated during the orientation. The participants wished that there had also been a practical aspect to the orientation in real work circumstances during which the instructor could tell them when to activate and deactivate the suit. Furthermore, the participants would have liked to hear about situations in which they could benefit most from the suit, such as changing diapers when the resident is bedridden.

> *“We should have tried it in practice right away, we don’t lift chairs here [like during the orientation]. […] I think that we should have gone to a resident, that would be really important. It would have given a feeling that I learn myself in practice and then I would perhaps have internalised it better…”*

The three-week testing period was felt to be too short to truly domesticate the suit in care work. As work at the facility was organised into three shifts, some nurses ended up having few shifts during which they could use the suit. Some of the participants mentioned that it should be used for at least six weeks, or even two to three months, to allow for better acclimation and to make it a more natural part of the work. One participant emphasised that people’s diversity affects the way they internalise new things, such as adjusting and using the exoskeleton.

Managers may end up having new tasks related to guidance and monitoring, for example.

> *“Normally these come via our managers, all these. […] And then it should be clear where you are supposed to use them and how. Who is involved, is it for everyone or just for some part of us or…? […] Somehow I think that if you say that we will purchase this [device], you should be using it then. So that it is not left lolling somewhere. And the use should be monitored, too, at some level.”*

### 1.4.4 Social domestication

Social domestication, which some scholars suggest should be added to the domestication theory (Søraa et al., 2021, p. 4, 11), highlights the social processes in technology domestication: how technology can enter into and become part of our social interactions. The social dimension of domestication investigates, for example, how humans relate to other humans when domesticating a technology, and it considers how technological domestication is not an individual process but one that relies on a wide variety of actors (Søraa et al., 2021, p. 4).

In social domestication, technology is seen as an actor impacting both the interaction between the end-user and the caregiver and that between other stakeholders (Goodall et al., 2019, p. 20; Søraa et al., 2021, p. 4).

Our results, as well as similar observations made by care workers during the field study, indicate that some of the residents did not pay any attention to the suit, while others showed interest in and asked questions about it. Both the workwear and the device were blue, so the suit did not stand out from the workers' clothing in any striking way. Some of the residents of the research site had memory diseases, and the participants wondered if this was the reason that these clients did not react to the suit at all. However, most of the family members of the residents did not pay particular attention to the suit, either, though some did ask about it.

> *"But I don't know of any wider positive… […] the residents were very positive about it, some did worry a little, yes, but it was the kind of general worrying that they may want to show as a kind of compassion towards nurses."*

> *"[A laugh.] A resident had three visitors and I took a dinner tray to the room. And I had this uniform on, and no-one said anything about it. Normally [they would]…"*

Within the work community, there was interest towards the suit, and other care workers were intrigued and curious to know about the benefits and user experiences. Care workers from other workplaces were also interested when they saw the suit:

> *"The colleagues asked these questions, yes, … that does it help? What does it feel like? And such things."*

Overall, discussions were characterised by curiosity and a neutral attitude. The participants felt that management and the organisation were supportive towards the research because they had been committed to it from the very beginning.

## 1.5 Discussion

In this research, the implementation and use of exoskeletons in social and health care were examined with the help of a field study concerning user experiences with the Auxivo LiftSuit exoskeleton. Analysis of the qualitative data with the help of the four domestication dimensions – practical, symbolic, cognitive, and social – revealed that there is potential for the domestication of exoskeletons in care work environments, as the participants noted many benefits and relatively few obstacles. There are, however, factors related to each dimension that either support or hinder the domestication process. These should be taken into account when introducing exoskeletons into care work environments.

From the practical domestication viewpoint, the exoskeletons were felt to be appropriate for certain work tasks. Nursing work includes many kinds of tasks, and the exoskeleton was beneficial for tasks that require leaning forward; the nurses wished they could reserve the suit for showering days, when much of the work requires leaning forward. Squatting positions, on the other hand, caused the suit to feel tight and uncomfortable. Planning concerning the order of work tasks and increased knowledge about situations in which the suit is beneficial are thus still needed.

Supportive factors included the suit's ease of use after initial adjustments and the fact that it was relatively unobtrusive and light. This is related to both the practical and symbolic dimensions; the suit did not attract special attention and was seen as a neutral tool. It was generally socially accepted, which relates it in turn to the social dimension.

Factors related to learning were largely practical but were also related to the cognitive dimension. When introducing the suit to workers, it is important to clearly mention the benefits of the device. Lucid guidelines regarding which tasks the exoskeleton is suitable for are critical, and the device orientation should include a practical exercise related to daily tasks. The instructor should explain when to activate the support and when to de-activate it; both reminders and time will likely be needed to ensure that nurses remember to activate the suit before appropriate work tasks. Importantly, all participants were ready to use some kind of an exoskeleton at work if they would gain benefits from the use.

The participants felt that societal appreciation of care work would perhaps increase through the development of such devices, which could lead to the voices of the nurses gaining more prominence. These findings are related to both the symbolic and social dimensions. On the other hand, the length of the three-week trial period was felt to be too short, and the need for longer implementation periods was expressed. This should be taken into account in future research.

## 1.6 Conclusion

The exoskeleton that was utilised in this research is a relatively simple device as compared to, for example, various types of active exoskeletons developed for rehabilitation. Nonetheless, various factors that either support or hinder domestication were found in this research. Technology domestication theory may thus provide significant help in research on exoskeletons or other novel types of technology that are introduced in care work environments, especially as it tackles questions of use and of nonuse with a holistic view of people's circumstances (Haddon, 2011, p. 319-320). This research also shows in a concrete way how the domestication dimensions overlap. The factors related to learning (the cognitive dimension), for example, turned out to be very practice-oriented (the practical dimension), and the neutral meanings (the symbolic domestication) of the exoskeleton supported its implementation in the care practices (the practical domestication).

Indeed, central prerequisites for domestication of exoskeletons in care work are likely to depend on several matters, such as the type of exoskeleton being used, the characteristics of the care work in question, the environment, the nurses' interests and competences, planning and organisation of the work, and even the health of the clients. This research paves the way for identification of the best practices for domestication – of the Auxivo LiftSuit, in particular – and thus for increasingly human-centred service design in care services.

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