Robots and the Future of Welfare Services

A Finnish Roadmap

http://roseproject.aalto.fi/en

ROSE

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Robots and the Future of Welfare Services – A Finnish Roadmap

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SUMMARY

This roadmap summarises a six-year multidisciplinary research project called *Robots and the Future of Welfare Services* (ROSE), funded by the Strategic Research Council (SRC) established within the Academy of Finland. The objective of the project was to study the current and expected technical opportunities and applications of robotics in welfare services, particularly in care services for older people. The research was carried out at three levels: individual, organisational and societal.

The roadmap provides highlights of the various research activities of ROSE. We have studied the perspectives of older adults and care professionals as users of robots, how care organisations are able to adopt and utilise robots in their services, how technology companies find robots as business opportunity, and how the care robotics innovation ecosystem is evolving. Based on these and other studies, we evaluate the development and use of robots in care for older adults in terms of social, ethical-philosophical and political impacts as well as the public discussion on care robots.

It appears that there are many single- or limited-purpose robot applications already commercially available in care services for older adults. To be widely adopted, robots should still increase maturity to be able to meet the requirements of care environments, such as in terms of their ability to move in smaller crowded spaces, easy and natural user interaction, and task flexibility. The roadmap provides visions of what could be technically expected in five and ten years. However, at the same time, organisations' capabilities of adopting new technology and integrating it into services should be supported for them to be able to realise the potential of robots for the benefits of care workers and older persons, as well as the whole society.

This roadmap also provides insight into the wider impacts and risks of robotization in society and how to steer it in a responsible way, presented as eight policy recommendations. We also discuss the ROSE project research as a multidisciplinary activity and present lessons learnt.

TIIVISTELMÄ

Tämä tiekartta tiivistää kuusi vuotta kestäneen strategisen tutkimuksen neuvoston rahoittaman monitieteisen tutkimushankkeen Robotit ja hyvinvointipalvelujen tulevaisuus, jonka keskeisenä tavoitteena oli arvioida robotiikan tarjoamia teknisiä mahdollisuuksia ja niiden soveltamista ikäihmisille tarkoitettujen palvelujen tuotannossa sekä samalla arvioida alan kehittymistä lähitulevaisuudessa. Tutkimusta on tehty kolmella tasolla: yksilön, organisaation ja yhteiskunnan.

Tiekartassa keskitymme erityisesti ikäihmisten hoito- ja hoivapalveluihin ja tarkastelemme ikäihmisiä ja vanhuspalveluiden ammattilaisia robottien käyttäjinä sekä hoito- ja hoivaorganisaatioita teknologian hyödyntäjinä. Analysoimme teknologiayritysten liiketoimintamahdollisuuksia ja luomme kuvan alan kehittyvästä innovaatioekosysteemistä ja robotiikan roolista sen osana.

Olemassa olevan tutkimustiedon ja projektin yhteydessä tehtyjen omien tutkimusten ja kokeilujen varassa arvioimme palvelurobottien hyödyntämiseen ja kehittämiseen liittyviä sosiaalisia, eettis-filosofisia ja poliittisia vaikutuksia ja sekä robotteihin liittyvää julkista keskustelua.

On osoittautunut, että robotiikka teknologiana on edelleen monelta osin epäkypsää ikäihmisten palveluissa sovellettavaksi. Tämän hetken toimivat sovellukset ovat hyvin rajattuja käyttötarkoitukseltaan. Visioimme sitä, mikä on todennäköisesti teknisesti mahdollista viiden ja kymmenen vuoden kuluttua. Jotta robotiikan hyödyt realisoituvat, samaan aikaan tulee tukea organisaatioiden kykyä ottaa uutta teknologiaa käyttöön ja kytkeä se osaksi palvelutuotantoa.

Tarkastelemme laajemmin robotisaation vaikutuksia ja riskejä yhteiskunnassa ja miten sitä tulisi luotsata vastuullisesti. Esitämme politiikkasuosituksia ja uusia tutkimussuuntia kohti kestävää robotisaatiota. Lopuksi pohdimme hankkeen monitieteistä luonnetta.

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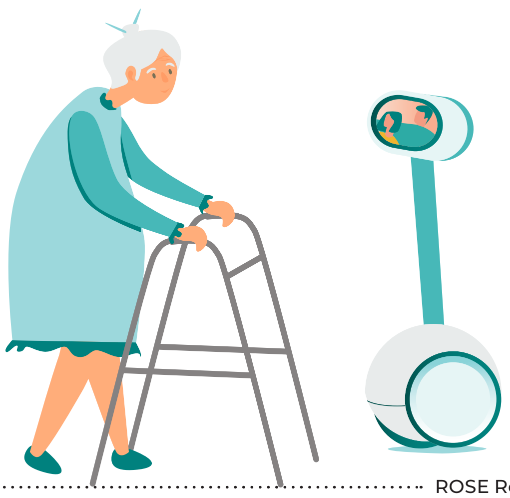

1 INTRODUCTION

Contributors: all (see the Appendix)

Currently, there are several parallel revolutions taking place, such as the strong growth of demand in care services for older adults due to the growth of the aging population, digitalization and automatization of these services, and the emergence of robots outside the industry for service tasks. The external global shock, the COVID-19 pandemic, is furthermore challenging the prevailing socio-economical and health care service systems, and simultaneously opening space for new technological options in care. Physical robots[1] , or simply 'care robots' that assist in healthcare and care services, are one of these options.

Care robots are believed to offer great potential for increasing productivity and improving the quality of services, and improving the wellbeing of patients, customers and care workers (e.g., Finnish Institute for Health and Welfare, 2020; Swedish government, 2018; Kangasniemi & Andersson, 2016; 'New Robot Strategy' of Japan, 2015). Promises and expectations have been high but there have also been questions like how and what type of robots should be applied in care and how they change care practices, work organizations and care managements. With this roadmap, we aim to provide an overview of current and expected future robotic applications that assist in care services for older adults as well as the possibilities and limitations related to their use and adoption in care. The roadmap gathers the research carried out in years 2015-2021 in a project Robots and Future of Welfare Services (ROSE)[2] and sets these findings into the context of wider scientific and societal discourse. This roadmap thus provides research-based insight into what the future contribution of robots could be in care for older people in general and especially in the context of Finland, and what policy and research actions should be taken as a result.

The ROSE project has been mainly – but not only – concerned with robots in care for older people: robots that could assist the ageing people and the care professionals working with them, and robots that could enable new arrangements of housing and services for the ageing population. Finland is one of the fastest ageing country in the world. This ageing curve is especially steep still in the next 10-15 years: in 2020, about 23% of the whole population of Finland was aged 65 years or older. In 2030, the number is estimated to rise above 26% (appr. 1.5 million people), and in 2070, above 33% (Official Statistics Finland: Population projection 2018).

Although ageing people are healthier compared to earlier decades, the Finnish workforce and care workers are getting older, and the dependency ratio is weakening. People are expected to work longer and retire later, but simultaneously, there is a lack of care workers. These societal trends pose a challenge to how the social care and healthcare for older people should be organized and financed in order to ensure the quality of life and high-quality services equally to all citizens at a reasonable cost, also in the future.

Compared to other assistive tools and technologies, robots certainly have unique practical potential to assist older adults. Robots that carry out tasks in the physical world with physical objects and in collaboration or even in contact with human beings might be able to support the activities of daily life. Both Finnish and international studies indicate that older persons need help with light and heavy housework, cooking, washing and bathing and going to bank or shopping (Boerner et al., 2016; Hammar, et al., 2008). Around 40–50% of Finnish older homecare customers need help with moving outdoors and 10–20% with walking 400 meters and using stairs (Hammar et al., 2008).

Other needs for support are related to cognitive functions. Approximately 200,000 Finnish citizens suffer from a memory disease and half of them have at least a moderate-stage memory disease; every year another 14,500 persons are affected (MSAH, 2020). Furthermore, there are social and emotional needs, such as widely reported need for help with socializing and loneliness (Boerner et al., 2016; Hammar et al., 2008). The most often mentioned psychological difficulties for older people are related to loneliness, lack of autonomy (dependence on caregivers) and fear of falling (Mast et al., 2010). The quality of life of older adults could be

[1] As defined in Chapter 2. The roadmap does not include e.g. software robots or "intelligent agents" that do not have a physical implementation, or simple monitoring systems.

[2] http://roseproject.aalto.fi/en/

improved with meaningful activities (Hammar et al., 2008). Could robots that remind a person of medication and eating, help them in orienting and planning the day, or even master social interaction provide help with these needs? These issues have only increased due to the COVID-19 pandemic and the requirement for social distancing.

Robots in care for older people raise questions of how well the robots can actually meet these needs with their prevailing technical and human-robot interaction capabilities. The question also arises of how well care professionals can utilize robots as an advanced technological tool in human-centered care services, how well the service provider organizations can integrate the robots into their processes, and what type of impacts the implementation of robots in services can have. If there is demand for robots in services, is there supply of robotic products and robot-based services that are mature enough to be adopted in care services, or by older consumers? We have approached technology companies and asked them this question to find out how they position themselves in the care robot market. In the larger view, the question is about the national care robotics innovation ecosystem and how it is evolving.

Finally, we can consider care robots at the level of the national policy making. Since 2017, there have been significant attempts to renew and reorganize the social and health care system as a whole in Finland. A process to find a political model that solves the challenges of a rising age dependency ratio and increased costs in future services has been described as a long gauntlet (Valli-Lintu, 2017; 2019). At the same time, the reform and its renewed service systems have been perceived as a potential catalyst for innovation and as a possibility to develop the national reference markets for health technology[3]. Another policy issue is the goal of increasing ageing people's participation in the working life. The Finnish pension policy, rehabilitation and training of working-age people and support for employment have allowed the working-age population to extend their careers. Within the context of technological change and its conditions and needs, digital leaps and the robotization of work in the service sector should be assessed in relation to these macro-level developments. The structural changes in the service system or in the behavior of the working-age workforce in the labor market can provide new opportunities for development and introduction of social and technological innovations.

The topic 'robots and the future of welfare services' poses several questions, but this project has had limited resources, and the participating researchers have had their own interests and scientific backgrounds on which they have based their research in the project. Certain interesting or relevant research topics have been mostly out of the scope of the project. These include macro-economics (productivity, care labor demand, worker re-skilling), robot-related technologies (artificial intelligence, software robotics, intelligent agents), or technical infra that is needed to fully utilize robots (advanced networks, integration of robots to other information systems). As mentioned earlier, this project has focused on care for older adults, and this focus has mainly excluded other potentially fruitful application areas within the welfare service domain.

Nevertheless, the ROSE project has been a multidisciplinary endeavor that as involved researchers in a wide range of disciplines, from human and social sciences to engineering sciences conducting academic research and carrying out several pilot studies to understand the role of robots in care services for older people both widely and deeply. In particular, this project has studied

- How people perceive and accept care robots, both in general and concentrating to various applications
- How robots apply and are taken into use in care services and organizations
- What kind of impacts the implementation of robots have
- How technology companies perceive care robots as a business
- How the care robotics innovation ecosystem is evolving
- What ethical and philosophical analysis of care robots reveals about their applicability in care
- The technical opportunities and challenges of care robots and what can be expected within five to ten years

[3] Healthtech Finland 2017: https://healthtech.citrus.dev/en/node/238

These research topics form the structure and contents of this roadmap. Overall, the research has been carried out on three levels: individuals, services and society (Figure 1), to capture the phenomenon of use of robots in care. Subsequently, this roadmap will identify new relevant research directions but also provide policy recommendations on the role of robotics in care.

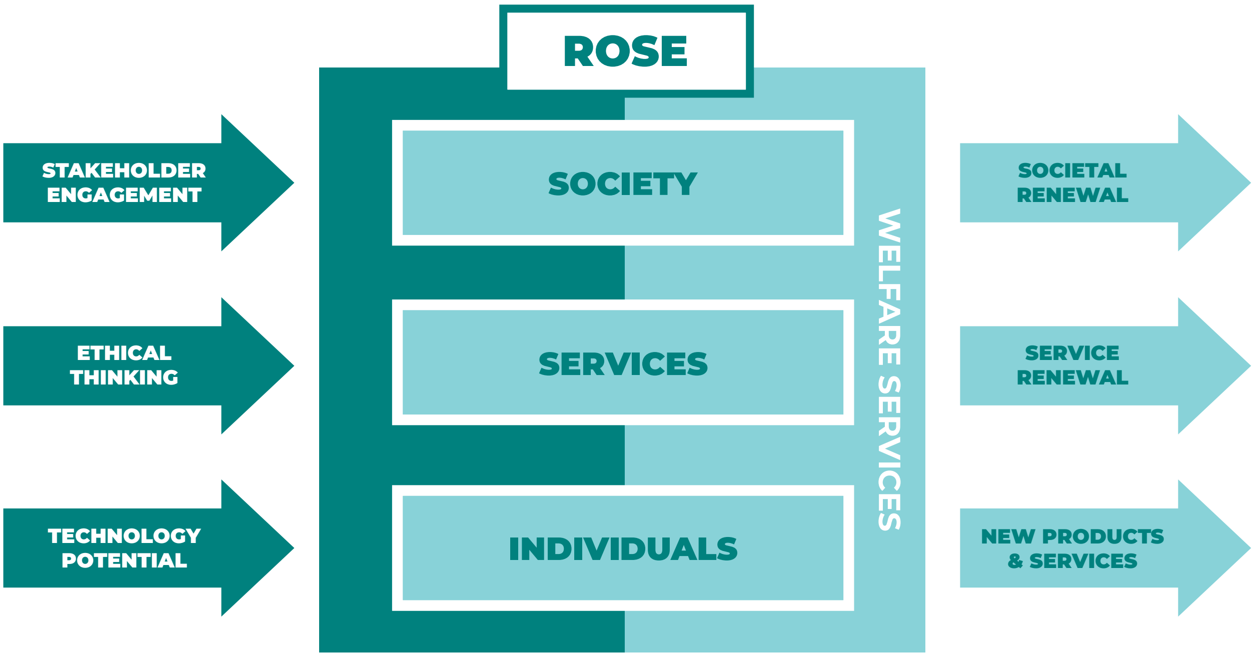

Figure 1 Research in the ROSE project has been carried out on levels of individuals, services and society

The ROSE project has published an earlier version of this roadmap in June 2017 (Kyrki et al., 2017). Now in 2021, the basic premises remain mostly same but with stronger research-based evidence than over three years ago. Application of new robotic technologies has not advanced as rapidly as many projections expected, but the big picture of the ageing population and needs for technologies have mostly stayed the same – except for the COVID-19 pandemic and the sudden demand for telecare technologies. It remains to be seen whether the pandemic will have such a profound impact on both supply and demand of technologies in care that care robots - that are predominantly very simple tools still - will advance enough to overhaul the care processes or everyday work. Another trend that was not considered in the 2017 roadmap but has since become relevant is the ecological and climate sustainability of robotics. Instead of promoting the use of robots in care, should we attempt to reduce the dependence of healthcare services on electricity and high-tech? Although not studied in this project, the sustainability and responsible use of robotics or any other technology cannot be overlooked in the future. The policy framework that ensures that this technology will be utilized in a responsible fashion must be written now. This roadmap provides a starting point for that with regard to care robots.

The roadmap starts with a short introduction to robots and robotic applications in care (Chapter 2), followed by studies of end-users' perceptions of robots and how robots are adopted in care organizations, based on empirical research carried out in the project (Chapter 3). The next chapter (4) examines care robotics service and innovation ecosystems, emphasizing their current form as well as future challenges. Chapter 5 discusses ethical and philosophical aspects related to care robots. Chapter 6 presents technical opportunities and challenges of care robots, and the 5-10-year vision ahead with several alternative scenarios for robots in care. Chapter 7 sums up the results and explores a responsible future road for care robot development and presents policy recommendations and new research directions. The document concludes in Chapter 8 with lessons learnt in this multidisciplinary project work of six years.

The roadmap reflects the opinions of individual researchers, not the academic institutions they represent. The ROSE project's researchers that have contributed in this roadmap are listed at the end of the document. In chapters describing the research carried out in the project, we have specified the contributors by name to help the interested reader to look for additional information.

2 ROBOTS IN CARE

Contributors: all (see the Appendix)

A service robot is a robot which operates partially or fully autonomously (or as teleoperated) in a physical environment to perform services for the well-being of humans and equipment, excluding manufacturing operations[4]. Care robots are service robots that operate specifically in care-related environments and for care purposes, and they can be categorized by personal or professional use. In this roadmap, care robots have physical actuation capabilities, meaning that the robot can move itself. In addition, environmental changes may be brought about by the robot's social interaction. For example, a pet robot can operate by making audible sounds or changing its head position. We also include teleoperated robotic devices without any autonomic function into our analysis of care robots.

Robotics as a technology enables a wide variety of care robot types and functions. Typical examples include

- *autonomously navigating mobile robots* for transporting supplies
- *socially interactive humanoids* for recreation, therapy and social assistance
- *robotic exoskeletons, orthoses and prostheses* to assist bodily function or for rehabilitation
- *robot manipulators* to grasp and manipulate physical objects
- *remotely controlled robots* for teleoperation and telepresence
- *multi-purpose assistive robot* (Figure 2) able to carry out many useful tasks in everyday life in collaboration with human – in this list of examples, this is the only type of robots that does not have commercial applications yet.

Innovations in physical robot applications are closely connected to the progress taking place in the development of software and algorithms, such as computer vision, machine learning and conversational artificial intelligence. The central robotic capabilities of mobility, navigation, sensing, manipulation and human-robot interaction could be mixed in various ways to create multi-purpose robots that could, among other things, run at home monitoring the safety and wellbeing of the older resident, chat with the user and provide many types of assistance. The current state of the art of robotics only allows single-purpose or simple multi-purpose robots (see Chapter 6 for technical challenges and visions), but there are already many applications available that support the wellbeing of older adults or their care at home or in care facilities.

Figure 2 Care-O-bot is a multi-purpose robot research platform, developed in Fraunhofer, Germany (Photo: VTT)

[4] International Federation of Robotics https://ifr.org/

2.1 Robotic applications in various care environments and services

We have collected examples of current robot applications in Table 1, organized in seven use contexts related to welfare services for older people: domestic home, home care and other services provided at home; housing services and long-term care; large care facilities; facility rehabilitation; health services; and hospitals and pharmacies. There already are commercial applications of all of these (for a wider review, see e.g., Lehtinen, 2017). In most cases, they are one- or limited-purpose tools.

Table 1 Robotic applications in different care environments and services

USE CONTEXT	ROBOT APPLICATION OR SYSTEM	PURPOSE OF USING THE ROBOT
Domestic home **User:** older adult (possibly also family members)	Medicine dispensing robot[5] Robotic rollator[6] Robotic spoon[7] Social/telepresence robot with conversational agent for social interaction and assistance[8]	Independent living, maintaining the older user's (resident's) functioning capability at home Social robots support cognitive orientation, alleviate loneliness, provide entertainment, monitor for safety, connect to smart home devices
Home care and other care services provided at domestic home **User:** care personnel	Care worker's exoskeleton for lifting the patient[9] Medicine dispensing robot (personnel fills the robot)	Ergonomics of care workers Cost-effectiveness and improved scheduling of care work Reduction of errors with medicine taking
Housing services, long-term care facility, residential care **User:** residents and care personnel in the facility, family members of the residents	Entertainment and communication robots[10] Social robotics for non-physical rehabilitation and therapy (e.g., autism, depression, social skills)[11] Telepresence robots for resident-family communication and for medical personnel visits[12]	New tools for recreation and therapy Increased quality of life for the residents Increased participation of family members in the activities of the care facility PR value for the organisation Cost-effectiveness of medical care
Large care facilities **User:** care personnel	Mobile robots for transporting food, equipment etc.[13]	Reducing secondary tasks and physical load from care workers Optimising delivery process

[5] https://www.evondos.com/
[6] https://pubmed.ncbi.nlm.nih.gov/28873839/
[7] https://www.liftware.com/
[8] https://buddytherobot.com/en/buddy-the-emotional-robot/
[9] https://laevo-exoskeletons.com, tested with nurses, see Ch 3.2.3?
[10] https://palro.jp/en/
[11] Wada & Shibata (2007)
[12] http://gobe-robots.com/
[13] Unpublished field trial and study of a logistic robot at an elderly care facility by VTT and TUNI (2018-2019), see Ch 3.3.3

Rehabilitation at a care facility (or at home) **User:** care personnel, patient	Wearable[14] or fixed[15] exoskeleton for rehabilitation (for the patient) Robotic orthoses and prosthetes[16] (long-term use)	More effective rehabilitation and increased independency of the resident Ergonomics of care workers Cost-effectiveness of rehabilitation
Health services **User:** healthcare professionals	Laboratory tasks, measurements and analysis (e.g., self-service kiosk[17], mobile laboratory robot[18]) Telepresence robots for remote care[12]	High level of precision in monotonous and repetitive tasks Cost-effectiveness of healthcare services Tackling long distances (e.g., in countryside) and safety challenges (e.g., COVID-19 situation)
Transportation system and medical care in hospitals, pharmacies **User:** medical care personnel, other personnel in hospital (e.g., in logistics and cleaning) pharmacy personnel	Transportation robot for deliveries (meals, medicine, materials, waste)[19] Cleaning and disinfecting robots[20] Pharmacy robots[21] Robot surgical systems[22]	Cost-effectiveness of logistics and other processes Reduction of errors in medicine delivery Improved results of surgery Better clinical safety and hygiene

In domestic homes, robots can be used to support independent living and support better and more diverse use of care services at home. Robots are used by or in interaction with an older adult or family members, or by care professionals at home. Simple interaction and ease of use of the robot is necessary, as well as a smallish size and light weight, if carried by the home care worker (who is utilizing an exoskeleton to help lifting the older adult from bed, for instance). Socially interactive robotics and speech interaction, in particular, is interesting due to its promised intuitiveness of use. Current social robots are still very simple in their functionality but with the advances of conversational artificial intelligence, chatbots and social robots may be able to provide a new way of assistance and support to the older user. The older users at home would often benefit from robots that provide physical assistance for housework, dressing and hygiene, but apart from robotic devices supporting eating, drug-taking, walking and cleaning, there seems to be a lack of application of these purposes (Bedaf et al., 2015).

Care facilities for older people, such as care homes, provide more space with common living spaces (living and eating rooms, kitchens, bathrooms) and wider corridors than private homes. The space allows for larger robotic devices. Care workers could benefit from robots carrying out logistic tasks and other routine processes (such as food preparations and delivery). Robotic assistance in secondary tasks would allow the care workers to focus on helping and interacting with the residents. In long-term care facilities, robots could support the residents' social communication and engagement and thus alleviate social isolation from family members and friends. Telepresence robots are moderately mature technology for this purpose, as long as other factors support its use.

[14] http://www.indego.com/indego/en/home; https://global.honda/innovation/robotics/WalkingAssist.html
[15] https://www.hocoma.com/solutions/lokomat/
[16] https://openbionics.com/hero-arm/
[17] https://bewellinnovations.com/
[18] https://new.abb.com/news/detail/37301/abb-demonstrates-concept-of-mobile-laboratory-robot-for-hospital-of-the-future
[19] https://aethon.com/mobile-robots-for-healthcare/
[20] http://www.uvd-robots.com/
[21] https://newicon.fi/pharmacy-automation-in-pharmacies/automated-dispensing-system
[22] https://www.davincisurgery.com/

In rehabilitation, there are both fixed robotic solutions and wearable solutions. Both can give stable-quality, long-term assistance to a resident performing physical rehabilitation activities. They will also adapt to the resident's improving performance.

In health and medical care services, robots have been adopted to increase the efficiency of processes, improve care and decrease costs. Large, structured spaces and highly controlled processes can be suitable for robots that are already in industrial use as they are applied to medical purposes, such as transporting equipment, delivering medicine and performing monotonous, repetitive tasks. Surgery robots, which are teleoperated by medical staff, are expected to be used increasingly in surgery due to the high precision they allow in operations.

2.2 Robotic support and interaction in care

Use of robotic applications in care, or the so-called 'robotic care', can be categorized by the way in which the robot is integrated into the care and interaction with the user. In Laitinen et al. (2019), we differentiated between robot-assisted care and robot-based care (Figure 3), based on whether the main user and interacting agent (or the 'beneficiary') is a care professional (robot-assisted care) or an older adult (robot-based care). In robot-assisted care, the robot can be physically close to the older adult, for example when a caregiver uses a lifting robot, or the robot can be in the background when it performs delivery or cleaning tasks without interacting with the older adult directly. In robot-based care, the robot has direct interaction with the older adult, for example as a home assistant robot, or the robot is possibly assisted by a caregiver, such as in therapy when recreation robots are used in care homes. Robots that are teleoperated by the care worker and used locally by the older adult fall between these two categories.

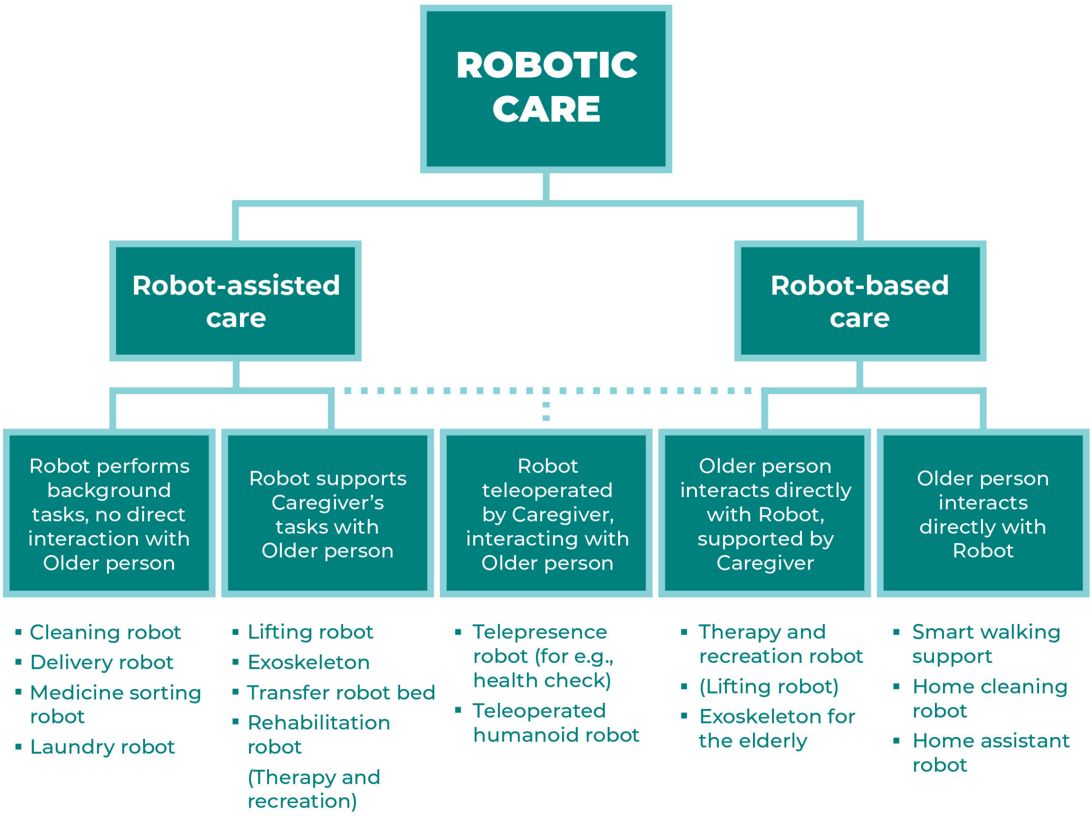

Figure 3 Categories of robotic care (modified from Laitinen et al., 2019)

The categorization is not comprehensive, but it displays some of the variety of interactive uses that robots are part of when integrated in care, and examples of the types of robots associated with those uses. In reality, given the variety of care environments, care services and people's roles, robot-assisted care and robot-based care are more of a continuum than two separable categories.

3 ACCEPTANCE, USE AND ADOPTION OF ROBOTS

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Do older adults and caregivers accept robots in care, and under what conditions? Is one robot better than the other considering the intention to use it? Are care organizations able to deploy robot solutions, and what type of support would they need? Figure 4 below illustrates the case studies and surveys we have carried out in the ROSE project in order to gather understanding of (1) how end-users – both older adults and care professionals – perceive and accept robots in care, and (2) what type of challenges care organizations and workplaces face when adopting robots into use.

The research methods mainly include surveys and interviews, but several of the studies were connected to long-term demonstrations or actual implementations of robots in authentic care or related environments. The findings from these studies are thus mainly based on the participants' first-hand experience of robots in their everyday life and work, in the context of healthcare and care for older people.

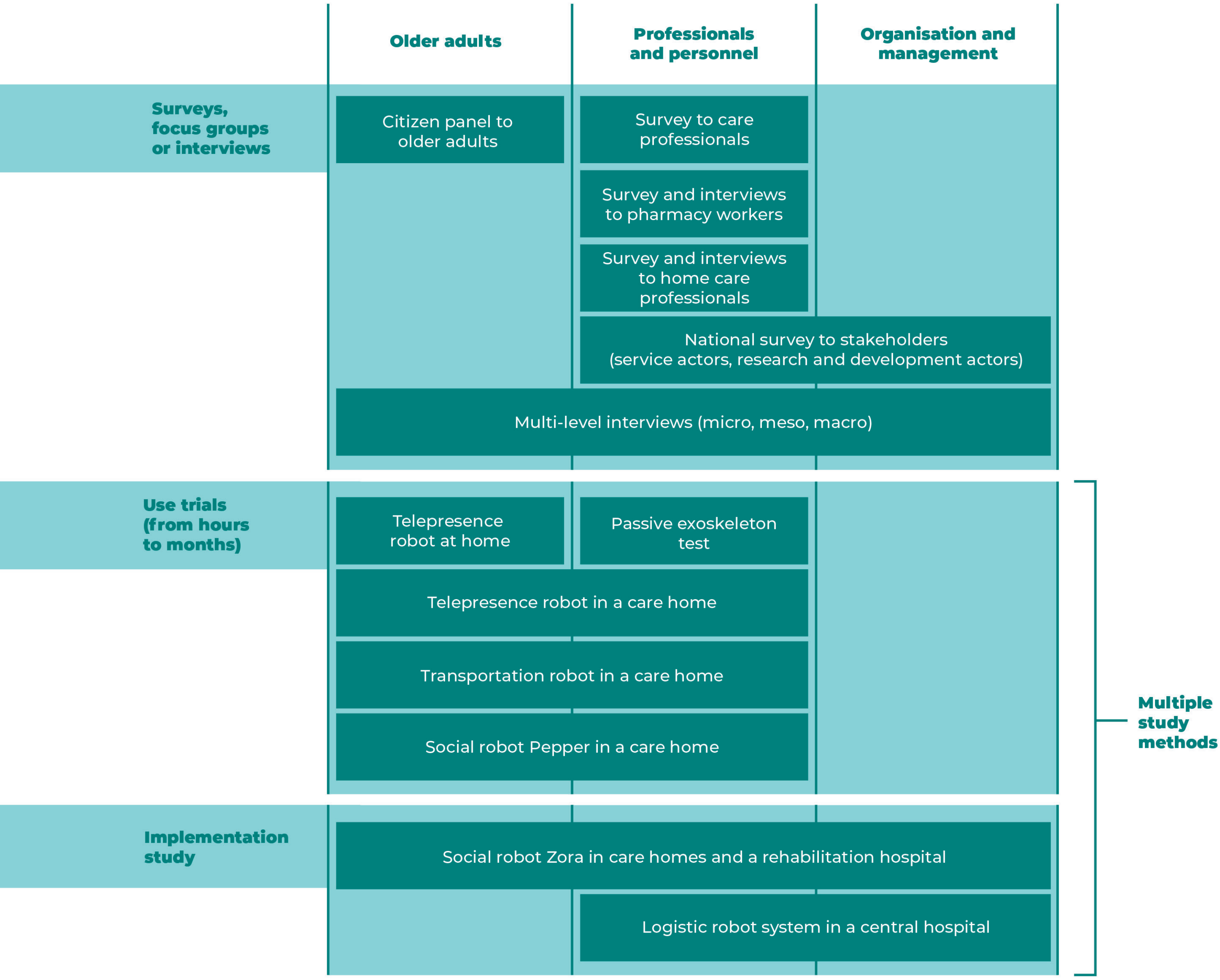


Figure 4 ROSE studies on how do older citizens, care professionals and organisations perceive and adopt robots in care

3.1 Older adults' perceptions of robots

In recent years, perceptions and acceptance of care robots among citizens and particularly older adults have been investigated in a number of research projects and other inquiries. We know, for instance, that Finnish people tend to perceive robots in a positive light but if asked about using robots to care for older adults and infirm people, perceptions are less positive (Special Eurobarometer 427, 2015). However, people are more willing to accept robot applications when they specifically support the independence of an older or handicapped person (Arras & Cerqui, 2005; Broadbent et al., 2009) or help in daily household routines or heavy tasks such as cleaning and carrying things at home (Ray et al., 2008).

Social robots are a special case of care robots, purposefully designed for natural interaction and communication with people. Although social robots still have limited capability to verbal dialogue and other interaction, people usually enjoy the interaction. Older persons are willing to talk with social robots (Vandemeulebroucke et al., 2017) and even build long-term relationship with them (de Graaf et al., 2015). On the other hand, the ethics of social care robots have been questioned. One concern is whether social robots lead to decreased human contact and social isolation for older people (Vandemeulebroucke et al., 2017). In the ROSE project, we have analyzed some of these ethical aspects – namely, how care robots influence human dignity, autonomy and loneliness – in terms of philosophy. This will be discussed in Chapter 5.

In order to explore older Finnish adults' perceptions of care robots, we carried out a citizen panel of older adults in collaboration with the Finnish Institute of Bioethics (Niemelä & Melkas, 2019; Saxén, 2017). We engaged a volunteer group of 25 older persons to learn about and discuss care robots, facilitated by the researchers. The purpose of the panel was to gather insight into older adults' perspectives on robotic care and their arguments about the acceptability and ethics of care robots as part of their possible future lives and care. As the results of the panel indicate, five important values were recognized influencing the participants' consideration of the wide-scale adoption of care robots in society: autonomy and control; knowledge and education; ethics and accountability; justice and equality; and human care (Table 2). Although the study had limits in terms of representativeness of the participants (see Niemelä & Melkas, 2019), we can conclude that there are older people who feel positively about robots, and some of them have positive ideas about using robots for social and emotional purposes. It is crucial that the robots support the autonomy of the user. This also extends to the introduction and use of the robot: the older person should have control over how the robot is used and whether it is taken into use in the first place.

Table 2 Five values of importance for the participants in the citizen panel (Niemelä & Melkas, 2019; Saxén, 2017)

Value/boundary condition	Description
Autonomy and control	Importance of supporting the autonomy of the elderly and control over the robot, as well as their autonomy in allowing robots to be used in personal care
Knowledge and education	Desire for more knowledge and education about care robots for both the elderly and caregivers
Ethics and accountability	Importance and transparency of safety issues, ethics, and legal accountability regarding care robots
Justice and equality	Emphasis on justice and equality in providing care services to people, even when robots are part of the service
Human care	The priority of humans in care, particularly for social and emotional needs

3.2 Care personnel's perceptions of robots

To find out the views and experiences of care professionals of the use of robots at work, we conducted two empirical surveys.

In 2016, 3,800 Finnish geriatric care workers participated in a survey on their expectations and experiences with care robots (Turja et al., 2018). The data were collected in collaboration with two trade unions, The Finnish Union of Practical Nurses and The Union of Health and Social Care Professionals in Finland. The questionnaire used robot definitions and illustrations from the Eurobarometer questionnaires (Eurobarometer, 2014), showing a food-processing industrial robot gripper and a butler-like service robot (Care-O-bot 3) serving a drink. Care workers' attitudes toward robots were compared to general population's attitudes toward robots, based on the Eurobarometer data (N = 969) (Turja et al., 2018).

Healthcare professionals had less experience with robots and more negative attitudes towards them than the general population. Managerial status and previous experiences with robots consistently correlated with robot acceptance in both of sets of data. Among the care workers, the participants had previous experience in using household robots rather than care robots. Among occupational groups, practical nurses stood out as having the most reserved attitudes towards robots than registered nurses and physiotherapists, for instance (Turja et al., 2018).

The second survey was conducted with home care professionals in two phases, before a robot intervention (2016, N = 200) and after the intervention (2019, N = 162) (Rantanen et al., 2017; 2020). The average age of the participants was 43.5 years in 2016, and 46.5 years in 2019. Out of the participants, 94% were women. More than 60% of the respondents were practical nurses, approximately 20% were registered nurses (20.0% in first sample and 23.5 in second sample). The participants formed a test group and a control group. The test group consisted of home care unit employees, who participated in four robotics workshops and one extended robot pilot session. In those workshops and extended pilot sessions, participants were exposed to different robots, such as Omron Lynx, Zora, Pepper and Double. The control group included various Finnish care workers, such as physiotherapists, occupational therapists, and team leaders. The survey measured whether the robotic intervention influences the participants' attitudes toward robots. The primary objective was to reduce change resistance through a long-term process. (Rantanen et al., 2020.)

3.2.1 Perceived usefulness of care robots in nursing work and home care

Perceiving a technology as useful is a well-known factor of accepting and adopting the technology. Based on the geriatric care worker survey (N = 3800), nurses view robotic assistance as useful particularly in physically demanding tasks (Turja et al., 2018). This includes lifting heavy materials and moving patients. Current assistive tools made for heavy lifting are not efficiently used in healthcare. Nurses report assistive tools to be inconvenient to use especially in cramped spaces (Turja, 2016). This poses tough challenges for robot developers, as they must design robots that are both multifunctional and dexterous. Similar implications were discovered in the exoskeleton trial (see 3.3.5).

According to the home care survey (N = 162-200), home care professionals do not welcome robotics into their working environment easily if they do not perceive robots as useful in their work or for the (older) clients (Rantanen et al., 2020). It is essential that the robot is perceived as useful in practical (home) care tasks for it to be accepted (Rantanen et al., 2017). Home care personnel find robots applicable in providing reminders, guidance and promoting the safety of the older people. These home care tasks are easy for current care robots to undertake, and they do not require the interaction between a human and robot to be too close. Robots lifting people at home is perceived as a far-off vision. On the other hand, gathering human-robot contacts can also pose a challenge from the perspective of acceptance of care robots (Rantanen et al., 2018; Turja et al., 2018).

Those geriatric care workers who already had firsthand experience with care robots (Paro the therapy seal robot, Zora, Double) were eager to continue using the robots especially if they perceived the robot(s) as enjoyable and useful at the same time (Turja et al., 2020). The ease of use did not appear as a significant explanatory factor of the use intention, perhaps due to the high level of self-efficacy of the respondents (Turja et al., 2019).

3.2.2 Characteristics of care professionals motivated to use robots

Using the highly presentative sample of 3,800 geriatric care workers, we studied the motivations of care personnel to use robots. For this purpose, we developed profiles of those care workers who had the most positive attitudes toward the emerging care robotization. The most attitudinal readiness for care robotization was found in care workers who were generally (Turja et al., 2019):

- older in their age
- interested in technology
- did not believe robots causing technological unemployment
- felt like robots were accepted among their colleagues
- had lower job satisfaction
- had higher self-efficacy

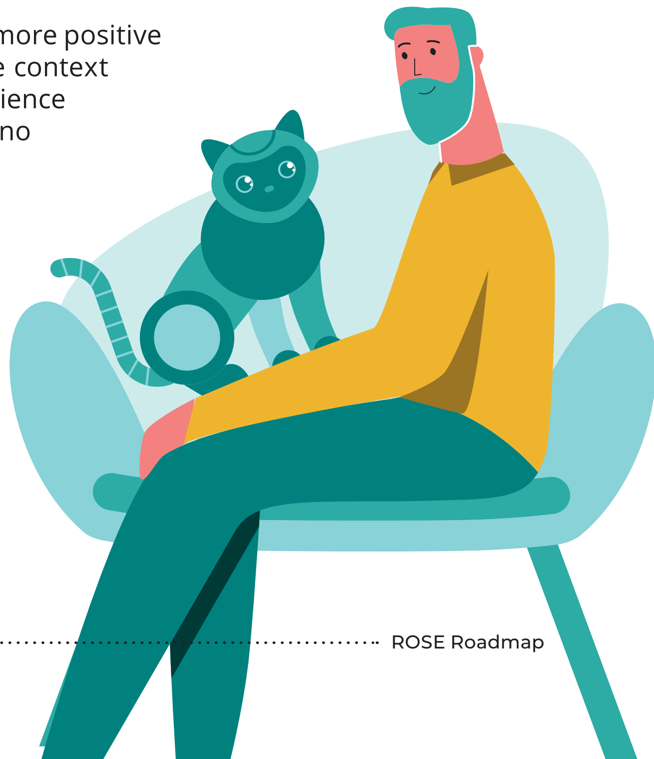
Some of the profiling results were more unexpected than others. Although younger people tend to have more positive attitudes toward robots, or even technology in general, Finnish care workers were an exception. Older respondents and those with lower job satisfaction had a significantly higher attitudinal readiness for robotization. This may indicate that their work is physically straining and that care workers have high hopes for new technology (Turja et al., 2018). These hopes may surface even more clearly when the care worker is ageing (Turja et al., 2019).

Self-efficacy refers to the care worker's beliefs in their capability to use care robots if robots were to assist them in their work. Finnish care workers reported extremely high level of robot-use self-efficacy and the minority of the respondents who had lower self-efficacy had more negative attitudes toward care robots. (Turja et al., 2019). Self-efficacy was constantly found to increase intentions to use care robots also in other survey studies.

In the survey for home care workers, a higher level of education correlated with higher use intention of care robots and higher self-efficacy toward the actual use of them (Rantanen, Leppälahti & Coco, in press). Consequently, it is important to pay attention to personnel training and constructing a robot-positive mindset when introducing care robots. In particular, the development of skills of care workers with a lower level of education should be supported (Rantanen, Leppälahti & Coco, in press).

Moreover, the social norm in the workplace correlates with attitudinal robotization readiness. If care workers thought that the majority of their colleagues would not welcome robots, they were likely to refuse robotic assistance themselves (Rantanen et al., 2018; Turja et al., 2019; Turja et al., 2020).

Any personal experience with robots was found to correlate with more positive attitudes toward robots that would be used particularly in a care context (Turja et al., 2018). For instance, head nurses reported more experience with robots compared to practical or registered nurses with no managerial experience (Turja et al., 2018). Head nurses were also more involved in planning assistive equipment purchases in the workplace, and they had more positive attitudes towards robots (Turja et al., 2018). This indicates the benefits of inviting different-level employees to participate in robot trials and pilots. After all, it is not sustainable and far-reaching if only head nurses accept care robots but the technology is supposed to be used by everyone in the workplace.



3.3 Empirical studies of robots in care for older adults

In this chapter, we analyze the use of robots and user experiences in cases when a robot has been implemented and installed in the authentic living environments of older adults, typically care facilities, for longer periods of time. In these studies, we were able to investigate more thoroughly how both older adults and care workers learned to use and interact with the robot; how other people, such as family members, were influenced by it; and how were the robots integrated into the actual care services. These studies included four different robots: a telepresence robot, a mobile transportation robot, and two social robots, humanoids Pepper and Zora (Figure 5). The first three studies with the telepresence robot, Pepper and the transportation robot were field demonstrations and studies in long-term care facilities. The fourth study was a long-term implementation study in which a Zora robot was permanently taken into use in care services in a medium-sized city in Finland. The study addressed the impacts of the robot on the stakeholders, such as older adults and care personnel. In addition to these four robot studies, we present a field trial of care workers wearing a passive exoskeleton in a care facility.

3.3.1 A telepresence robot for older adults to communicate with family members

The telepresence robot Double (Figure 5a) was tested for the way it supports the remote communication with a resident in a long-term residential care facility (Niemelä, Van Aerschot, et al., 2019). We arranged a series of three longer-term trials in two separate residential care facilities: one 12-week trial in a private facility, and two successive 6-7-weeks trials in a public facility. In each trial, we installed the telepresence robot in a room of a long-term care home resident for communicating with her/his family members. The qualitative interview data included the perspectives of the residents, her/his family members and care workers at the ward.

The results confirmed the potential of telepresence robots in assisted living for older people in order to increase the presence of family members in the resident's life and vice versa; the study also provided insight into how the increased presence of family members may affect the care work. However, technical issues such as the quality of sound, the size of the display

Figure 5 From left to right: a) Double the telepresence robot located in a resident's room in a care facility (photo: VTT). b) Social Pepper robot (photo: Jaakko Porokuokka). c) The logistic robot MiR carrying food and supplies in a care facility (photo: VTT). d) Zora, a small social robot, used by an older adult (photo: Satu Pekkarinen). e) Passive exoskeleton vest to alleviate nurse's physical strain when lifting patients (photo: Päivi Tommola)

and the quality of the video image were not good enough to allow engaging, undisturbed human-human interaction over the robot. The remote driving of telepresence is the key issue that separates it from any video communication method, and there are needs for that in remote communication and care, but the driving interface needs to make the remote user feel confident about driving before it can be utilized. Furthermore, a remote visit over the robot is different from an actual physical visit of a family member in the care home. The telepresence robot was seen as violating the privacy of other residents and the care personnel. If a family member wants to drive the telepresence robot in public areas of the care home in addition to the resident's room, it should be agreed on with all residents and the personnel beforehand.

Double has also been tested in a home environment (unpublished study). An older couple living in a rural area and far from their children took the robot to their home in autumn 2020 (during the COVID-19 pandemic). We trained two adult children and one grandchild to use Double. The five-week study focused on the quantity and quality of communication between family members through Double. According to the experiment, the couple felt that it was easy to communicate with family members and the communication had more intimacy compared to telephone calls or videocalls. They also emphasized the increased feeling of safety. The family members shared these experiences.

3.3.2 The Pepper robot in a care home

We explored the way older residents in a care home learned to use and interact with the Pepper robot (Figure 5b) using the Living lab methodology. We wanted to engage older adults to participate in cocreating new services in a care home (Lehto & Rantanen, 2017). There were two pilots. In the first pilot, a robot was programmed with three applications that had been developed based on the input from earlier research. The first application was designed to stimulate seniors' memory through music and historical trivia from past decades. The second application allowed listening to news by the Finnish national broadcasting company. The third application was an email-based messaging service utilizing face recognition. In the second pilot, a talking book service, Selja Library, was added to Pepper. The services were entirely voice-controlled.

In the first pilot, the robot was placed in housing services in a unit with 10 older adults for five weeks to interact with the residents. Located in one of two living rooms, the residents were instructed to use the robot as they wish. The workers and residents were instructed how to operate the robot and technical support was provided when required. The use of the robot was documented using a locally installed camera. Following the pilot, the residents were interviewed individually, and the home care workers were interviewed as a focus group. As part of a larger survey, the changes in care workers' attitudes towards robots before and after the pilot placement were measured. In the second pilot at enhanced housing services, Pepper was placed in the hall. Workers were taught to use it with the residents. Pepper was in that unit for seven weeks.

The qualitative findings show that the residents were capable and willing to use a humanoid robot as an interface for digital services. The utility of the robot is related to the services it is capable of rendering. The Pepper robot seemed to be a welcome addition to the everyday life of the unit. While the service selection available on social robots is modest, the current generation of social robots appears to provide a sufficient level of usability for the residents to use the social robots independently. The residents could operate the services using the robot with little instruction, and the caregivers did not consider the robot to increase their workload. Quantitative research data displays no improvement in the care personnel's attitudes towards robots, regardless of the large number of pilot placements conducted at the premises. In enhanced housing services, the use of Pepper robot rested on the shoulders of a few workers, although they were all taught to use it. The residents were keen on Pepper but did not want to use it very much.

3.3.3 A mobile robot transporting meals and equipment

In this study, we investigated whether transportation robots can be applied in assisted living facilities to reduce the workload of care workers (Niemelä & al., manuscript in preparation). Preceded by a co-design process and two preparatory short-time trials in two residential care facilities, we installed a MiR transportation robot (Figure 5c) in the other facility for a three-month field trial. The robot assisted care workers in their daily transportation tasks by carrying meals and supplies. The robot was programmed to autonomously navigate between the kitchen on the first floor, the lift, the residents' room doors on four floors, and the charging station; altogether about 50 stops. The care personnel used a mobile phone application to control the robot and send it requests to navigate to a certain pre-programmed stop, at which the personnel filled or emptied the robot. The robot was not able to operate the lift, and a care worker usually walked close to the robot to assist it with the lift, and to watch over the encounters with the residents in places like narrow corridors. Data collected during the study included observations, interviews of care workers and management, group discussions with facility residents and the robot usage log.

As a result, we could observe signs of increased efficiency at work: the robot freed care workers from pushing food trolleys to make phone calls and communicate with each other and residents during transportation tasks. With the robot, one care worker could deliver meals to all resident rooms, which freed other workers to assist those residents that ate together in the dining room. Many care workers were motivated to learn and use the robot to facilitate their work, the management was committed and encouraging during the trial, and the kitchen personnel was willing to change their work to utilize the robot. However, we found that the facility was too complex, dynamic and safety-critical as an environment for easy, smooth adoption of the transportation robot. Challenges observed were both technical and organizational. The building had narrow corridors, glass fences and doors etc. that were problematic for the robot's navigation. The older residents sometimes felt unsure how to give way to the robot, or whether the robot was intelligent enough to avoid them with their slow moving. The key users in the organization changed in the middle of the field study due to reasons not related to the study, but this left a gap in the use of and learning to work with the robot. To make the most use of the robot transporting meals, more process co-design would have been required between the kitchen and care personnel. However, the personnel participants recognized the potential of the robot and wished that they could use the working time freed from transportation tasks with the residents. As a design guideline, the robot should be more respectful to the residents and clearly step aside from their paths, to avoid awkward human-robot 'negotiations' in cramped spaces.

3.3.4 The Zora robot in care homes and a rehabilitation hospital

The longitudinal multi-perspective research on Zora robot implementation in care services was conducted in 2015-2019. As a humanoid robot, Zora (Figure 5d) is advertised as being capable of assisting in exercising and rehabilitation. The research consisted of a field study on the implementation phase and follow-up interviews after three years of use. The field study was conducted in December 2015– April 2016, when Zora was introduced to the care services for older people in the city of Lahti. It was the first Zora in the public elderly care services in Finland.

The data on the implementation phase consisted of semi-participatory observation, focus group interviews of care workers, clients and social and health care students, and individual interviews of the management (as well as comments in the public media) in January-April 2016. In addition, seven follow-up interviews (care personnel from three units and managers) were conducted in spring 2019.

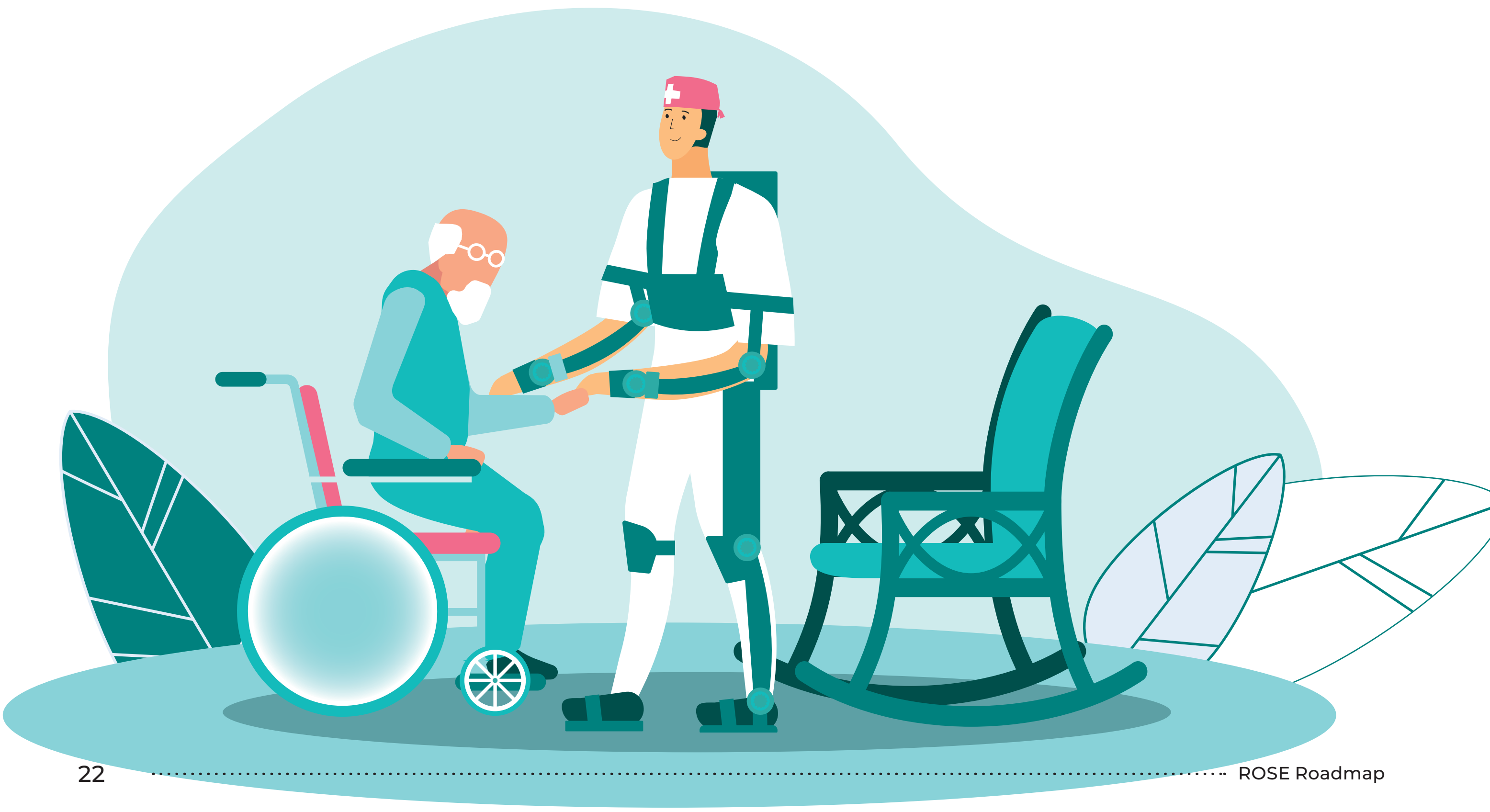
The field study results (Melkas et al., 2020) on the implementation phase showed that the robot's presence stimulated the clients to exercise and interact. The care workers perceived the clients' well-being both as a motivation to learn how to use robots as well as a justification for negative views. The robot use was associated with multiple types of impacts with positive, negative, and neutral dimensions. These included impacts on interaction and activity for clients, and impacts on the work atmosphere, meaningfulness of work content, and professional development for care personnel. Impacts on personnel were related, for example, to the need for orientation, problems of time usage, and overall attitudes toward the novelty and renewing of care service. Many of the identified impacts were related to how the robot fit into the service processes. To summarize, Zora had the potential for multi-faceted rehabilitative functions and to become part of care services, but the need for careful systemic planning became clear. The follow-up study results (Pekkarinen et al., forthcoming) show that even though the care workers felt that the robot was a nice 'messenger' of robotics and that it brough new interesting challenges to one's work and recreation for clients, the robot-assisted service was not rooted in the daily services of the care units. This is due to the changes in the organizational structures, and changes in personnel and tasks, which had led to shortcomings in the provision of information and processes related to the long-term robot use.

3.3.5 Exoskeleton for care personnel

Exoskeleton trials (Turja et al., 2020) were conducted during 2019 and 2020. Despite the low-tech type of the equipment (Figure 5e), the trials were justified due to the need to investigate the opportunities wearable technology has on making care work less demanding physically. For instance, one manufacturer has reported studies in which a passive exoskeleton relieved lower back workload by 50% (see Turja & al., 2020).

In the first pilot study, qualitative experiment data and supportive statistics were gathered from nurses and nursing students (N = 16) assisting a geriatric patient from a hospital bed into a wheelchair. The experiment was conducted in a controlled environment (Tampere) and proceeded in three stages. First, the nurses assisted the patient without exoskeletons; then, one of the nurses wore an exoskeleton; and lastly, both nurses wore an exoskeleton. In the following studies, exoskeletons were tested in authentic care home (Lahti) and home care (Riihimäki) environments where care workers (N = 8) used the exoskeleton individually for a longer period of time (such as one week). The participants were interviewed before and after the trial period, and they kept a diary on the use.

Most of the participants thought that the exoskeleton reduced strain on their lower back in patient moves. However, only half of the nurses reported intention to use exoskeletons in their actual nursing work. This future intention depended mostly on the level of trust (i.e., reliability and safety of the equipment) and the enjoyment of use. These statistics were supported by qualitative findings from the longer and wider-range trials. The trust is important in an environment that prioritizes patient safety. The enjoyment of use, then, would mostly benefit from a smaller size and softer materials. Exoskeletons would serve care work particularly well if they fitted under the working clothes.



3.4 Other studies of robots in organisations and at work

The empirical studies and surveys on care professionals presented above have highlighted the critical role of the care personnel in the introduction of robots in care for older adults. Robots do have potential to change the practices of care work, as was implied in the longitudinal Zora implementation study (3.3.4), and the study of a mobile transportation robot (3.3.3). In addition to these, we have investigated the pharmacy automation and the adoption process of a logistic robot system in a central hospital to understand the use and impact of robots at work.

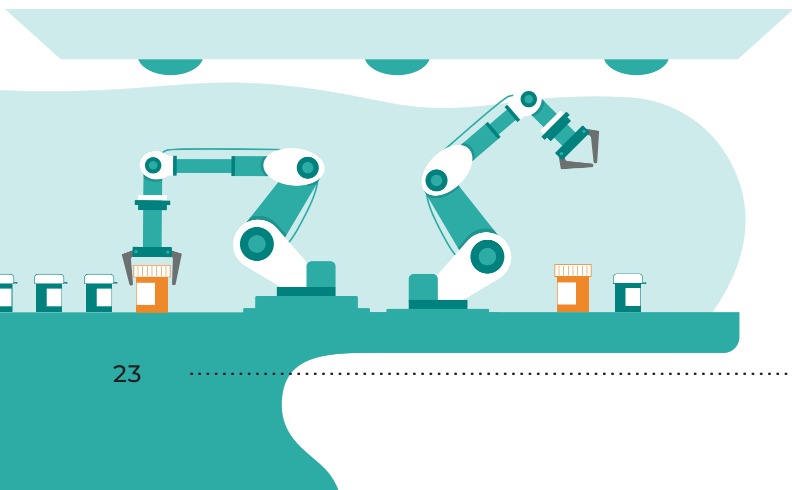
3.4.1 Medical dispensing robots in pharmacies

We conducted a survey to assess the effects of pharmacy automation in Finnish community pharmacies (N = 573). 53% of the survey's respondents were working in a pharmacy that used some manner of automation. In nearly all these cases this meant a dispensing robot. The survey was based around the technology acceptance model (TAM), and a statistical model was made to map variables that affected the perceived usefulness of pharmacy automation among respondents. The survey was also used in finding additional interviewees to understand the qualitative changes in automated pharmacies.

The results in Laakso (2020) show that pharmacy automation is perceived as more useful when it 1) is compatible with the values of the respondent, 2) supports autonomy and 3) does not increase the experienced technical time pressure. The model made from the survey data also shows a significant difference in the perceived usefulness between the technical assistants and the pharmacists. Additional interviews with the technical assistants revealed a change in their work assignments. Dispensing robots and the use of electronic prescription system meant that a major part of the technical assistants' former tasks was now automated. The technical staff seemed to have moved to more commercial and customer service -type assignments and to the handling of over-the-counter products in pharmacies. This is both similar to and different from an earlier study made in a hospital pharmacy (see Barrett et al., 2011), where a dispensing robot rearranged the resources and work visibility between the working groups in the pharmacy. However, in the hospital pharmacy setting there was no need for commercial tasks, and the assistants there felt their job quality lowering as their schedules became tied to the robot making their jobs more controlled and stressful (Barrett et al., 2011). Even though the assistants in the Finnish community pharmacy setting did not have similar experiences, they did show a lower perceived usefulness towards the robot and their tasks had changed because of it. The new commercial tasks made possible by the robot in this setting were experienced as interesting but the loss of their tasks relating to medical knowledge was also found regrettable in the interviews (Laakso, 2020).

3.4.2 A logistic robot system in a central hospital

We studied how a logistics robot system was taken into use in a large Finnish hospital (Talja et al., 2017; Lappalainen, 2019). The first two robots were implemented in 2016, and the final system was expected to include eight similar autonomous mobile robots performing delivery and transportation tasks, taken into use in phases over three years. The robots transported instruments between an instrument maintenance unit and three operational units, including the surgery outpatient department, and from the hospital's central storage to selected units (Figure 6). Other expected transported items included laundry, waste, food and medicaments.



In the early phases of the robot system implementation, six persons working in different roles in the hospital were interviewed (Talja & al., 2017). The personnel's and public's reactions were quite positive, except that concerns were evoked related to expected savings in personnel costs. The logistics robots were thought to affect the actual care work in a rather limited way. As the robots enabled 24/7 transportation, the disturbances of internal transport traffic to the personnel were reduced. Certain positive effects

Figure 6 Two TUG logistic robots waiting for the lift in a hospital (photo: VTT)

on the workflow were also identified: more daily transports enabled better availability of instruments, for example. The perceptions of the care personnel differed concerning their possibility to participate in the early phases of the implementation process. The instrument maintenance unit wanted more engagement. This reflects the different activities of the respective units: reliability of the instrument transports is directly related to the core task of the instrument maintenance unit.

Lappalainen (2019) further studied the introduction of the logistics robots to the hospital service system from a multi-actor network perspective with a longitudinal case-study approach. The study focus was on the complex dynamics, emerging practices and value-in-use of the robot adoption process. Aligned with implementation, two-phased interviews of different involving actors/professions in addition to observations were conducted during 2016-2018.

The empirical findings revealed complex interdependences in the dynamic hospital service system. All actors shared their conception of the systemic change boosted by the logistic robotic system to enable more efficient and customer-centric care work as a core service. However, the multi-actor insights and emerged new practices also showed the diversity with conflicting interests in terms of changing mutual roles, resource integration and related redesign possibilities. As a conclusion, three alternative design approaches were identified, such as 1) Adaptation, 2) Partial reconfiguration and 3) Restructuring. The adaptive design approach seemed to be dominant upon the introduction of a logistics robot system to the established hospital service system. However, there were also indications of partial reconfiguration and even restructuring (such as in instrument maintenance and central storage service).

Further, regarding these approaches, several general and service-specific spatial, temporal and technological boundary conditions were identified as both enablers and constrains. For instance, spatial changes (renovations, new facilities) provided opportunities for partial reconfiguring and even restructuring. Interoperability, reliability and usability of the technological system were prioritized in the adaption approach, while utilization rates of robots appeared to be the focus in partial reconfiguration, and autonomy and modifiability of robots appeared to be the focus in the restructuring approach. The study expands the knowledge base by making visible the dynamic interdependences of the networked actors and institutional logic hindering or enabling the technology-enabled systemic change. The further developed design framework provides guidelines for service designers, technology suppliers and hospital managers (Lappalainen, 2019).

3.5 Multi-level studies: the situational picture of robot use

In addition to the empirical studies and surveys described above, two multi-level studies were conducted that produced results that confirmed many of the issues brought up in the previous sub-sections. The multi-level character of these studies was important: research on care robots needs to address different levels and groups in society, because the use of care robots is a broad-based, systemic issue, and it requires understanding, involvement and collaboration between different groups of people, organizations, policies and sectors. Firstly, an online survey was conducted with a range of Finnish stakeholders (n = 250) including service actors (n = 148) and research and development actors (n = 102). The results concerning the innovation ecosystem aspects are presented in Chapter 4.2. The survey results also contributed to our knowledge of competence needs and attitudes, among others (see Tuisku et al., 2017).

Secondly, multi-level interviews were conducted at the micro-, meso- and macro-levels. At the micro-level, 18 individuals participated in the focus group interviews (older people, their relatives, professional caregivers, care managers); at the meso-level (organizational and community level), 12 individuals participated in semi-structured interviews (representatives of companies, interest organizations or associations of social and healthcare professionals, interest organizations or associations of end-users/ citizens (older people), organizers or providers of public social and healthcare services, and educational institutions for educating professionals for social and healthcare or welfare technology fields), and at the macro-level (societal level), 11 individuals participated in semi-structured interviews (representatives of political decision-makers, research institutes, insurance organizations, funding organizations, and the media). This set of interviews unearthed a multi-faceted picture of the situation in Finland (Melkas et al., forthcoming).

The interview study results showed that 'the door is open' for robot use in Finnish care for older adults. The pilots have offered several glimpses of it, but there is an obvious lack of information about the benefits of robot use and lack of understanding of robots' tasks in services, their integration into clients' services, collaboration between various stakeholders, and competence in management and procurement. The interviewees emphasized the problem of 'project-natured' pilots that do not lead to permanent activities. On one hand, there is inadequate, even skewed information about the real opportunities of robot use in care for older adults. On the other hand, people have exaggerated expectations for and fears towards the use of robots.

The attitudes of professional caregivers and clients towards robot technology varied, but it was turning positive at a general level, especially thanks to the pilots. Resistance was caused by the way in which robot use is marketed; marketing focuses on economic concepts only and underscores savings instead of the quality of care. At all levels, two issues were strongly emphasized: lack of information and competence, and economic factors. At the micro-level, several issues were emphasized: firstly, older adults need sufficient introduction into the robots that is given early on and individually, on each older adult's terms; secondly, professional caregivers need sufficient resources for learning, and it needs to be led, well organized and supported by supervisors; thirdly, the various ethical questions occupy caregivers' minds; relatives of older people recognize the caregivers' haste and hope that robots would increase the amount of human care. At the meso-level, the following challenges were emphasized: the one-off nature of pilots; levelling up of robots into the structure of the care system and vocational education; management and its support (related, for example, to resistance to change, and lack of shared national-level practices and guidelines). At the macro-level, the following challenges were highlighted: uncertainty of roles of different stakeholders; lack of a 'knowledge concentration', and inadequacy of steering and funding mechanisms. (Melkas et al., forthcoming)

3.6 Technology acceptance and workplace policy

Employee attitudes and capabilities are key factors when considering the added value and speed of implementating and adopting new technology and robots at work. Increasing evidence suggests that the traditional way of thinking and the technology acceptance model (TAM), which focus merely on individual perceptions and users' experiences of technology, neglect the realities of implementing technology innovations within organisations and in the interplay between the internal and external structures of the workplace (see Gallivan, 2001; Frambach, 1993; Chau & Tam, 2000; Frambach & Schillewaert, 2002).

In order to overcome this constraint and broaden the technology acceptance explanation model, we conducted a study using a representative nation-wide work and working conditions survey (N = 4,100) from Finland (Krutova et al., 2021a). The survey concentrated on working conditions and modern technologies – such as robots, artificial intelligence, and digitalisation – and their impact on the practices of work. Empirical findings suggest that both employees with high-general skills and low-general skills are sensitive to their treatment in the organization, but the highly skilled employees who used robots in their work were the most sensitive and critical when it came to the employees' voice, fair treatment or conflicts in the workplace (Krutova et al., 2021a). This important observation can also be seen as a real barrier to technological development and acceptance in the current structures of jobs, the polarisation of occupations and positions.

If this is the case, attention should be paid to supporting and empowering disadvantaged workers in workplace-level technology policy and development (Krutova et al., 2021b). Technological changes in the organisation should be built with different-level workers involved in decision making processes. The implication of this to care context is e.g. that when care organisations choose their "point of contact" for technological and robotic assistive tools, they should consider other than staff members who already have a supervisor status. Indeed, practical nurses are more interested in such representative posts than for example registered nurses, head nurses and other managers in healthcare (Turja, 2016). It is obvious that the construction of a technology-positive care culture is a long-term process, which requires training and development, technological development and strong strategic management at various levels (Rantanen et al., 2020).

3.7 Conclusions

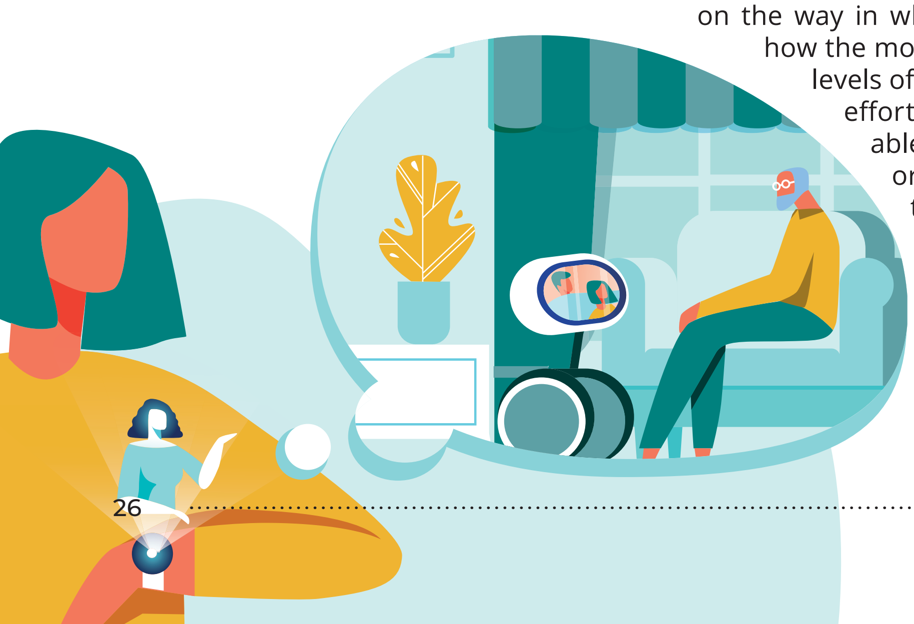
Robots can be applied to many useful roles in care for older adults. The older adults can be interested, willing and capable to learn and use them for various communicative, entertaining and rehabilitative functions as part of their everyday life. Older adults valued the independency, safety and assistance that a robot could provide for them in household tasks or engaging in social relationships. Care professionals in general request robots to help in physically heavy tasks such as carrying and lifting. Specifically, in home care, robots were seen useful for providing reminders, increasing the safety of the older adult and guiding physical exercises, but less useful for physical tasks or decreasing the loneliness or anxiety of the older adult. Care workers who perceive robots as not only useful but also enjoyable assistants have higher acceptance of robots.

Technical functionalities or the features and applications of care robots are in many cases not mature enough to allow for smooth interaction and usefulness in long-term use. Many of the robots may be too cumbersome for an older adult to use, and both home environments and care facilities remain challenging environments for robots. Moreover, as the studies with the transportation robot and Zora show, the adoption and use of the robot in care organizations can be heavily influenced by organizational factors such as changes in personnel. Involving different employee groups and providing sufficient training is necessary for a successful adoption process.

There is a specific profile of care workers that have a high attitudinal readiness for robotization in care: they tend to be older, have experience with robots, are generally interested in technology, do not believe that robots will cause technological unemployment, feel that robots are accepted among their colleagues and tend to also have lower job satisfaction and higher self-efficacy. To support these characteristics, future education of care professionals should include technical skills, use of care robots and programming, for instance, to ensure the personnel's trust in their ability to learn about new technologies.

Implementing and using robots in care is associated with diverse impacts on the clients and personnel. These impacts may have positive, negative, and neutral dimensions. Early impact assessment during the implementation helps reveal important points that require corrective actions and contributes to smooth implementation. This is required for robot use to be truly beneficial.

Technological development depends not only on technology, but above all on the way in which individuals and organizations adopt it, how the motivations and skills of employees at different levels of the organization are utilized, and how much effort the organization and its management are able to direct to the smooth transition in the organization. To make the most of the new technology and robots and the productivity they promise, the management of the organization must pay attention to the personnel issues and quality of the workplace over which they have control.



4 CARE ROBOTS IN THE INNOVATION ECOSYSTEM

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The societal and systemic levels related to the use of robots are still rarely discussed despite the efforts to advance the use of robots in welfare services and various countries' initiatives to produce robotization strategies for those services. New technologies such as robots contribute to broader societal changes with constant 'negotiations' with markets, policies, science, infrastructures, user preferences and thinking models – it is thus a question of a larger socio-technical transition (e.g., Geels & Schot, 2007) that we are undergoing when introducing and using robots in welfare services. Socio-technical transitions are radical innovations in structures, mindsets and practices that involve actors from different sectors, domains and scale levels (Loorbach et al., 2010). Wider and deeper understanding of the societal and systemic levels is therefore crucial. Ecosystem concepts provide some assistance in this task. Ecosystems consist of various interacting participants – typically a complex array of stakeholders in different sectors, with boundaries that are challenging to draw. Traditional innovation policies, often sector-based, may lead to sub-optimal solutions, generating even more persistent and complex problems over the long term (Loorbach & Rotmans, 2006). By focusing on the different levels and ecosystems, future research can hopefully help avoid this trap in the case of robots in welfare services (see also Pekkarinen & Melkas, 2019). While technological and service innovations co-evolve in this complex context, they also lead to a variety of societal implications that also require systems thinking.

This chapter discusses the ecosystem concepts – in particular, service ecosystem and innovation ecosystem – in the context of care robotics. These concepts relate to the societal and systemic level of the use of care robots, however with somewhat different emphases. Various ecosystem concepts have been introduced in the research literature (e.g., Valkokari, 2015), but in general, ecosystems are networks gathering complementary resources to co-create value (Moore, 1996). They involve cooperation, competition and interdependence (Adner & Kapoor, 2010). The ROSE research has adopted both the service ecosystem (Lanne et al., 2019) and the innovation ecosystem (Pekkarinen et al., 2019; Tuisku et al., 2017) perspectives. These three articles form the main basis of this chapter on robots in ecosystems. Even though different ecosystem concepts are used in the chapter (in line with the underlying articles), the main message of this chapter is related to *ecosystem thinking* in general.

4.1 The service (business) ecosystem

4.1.1 Study of technology companies shifting towards care robotics

A *service ecosystem* has been defined as being composed of heterogeneous entities that interact with each other to achieve shared goals (Wieland et al., 2012). Interactions and perceptions of what problem the actors need to solve can be expressed through such a collaborative framework that also highlights dynamic processes, including the collaboration and competition shaping institutional organizations (Wieland et al., 2017). Both introduction of new technology and institutionalization of solutions are needed for new markets to arise (Vargo et al., 2015). Markets are also continually formed through the activities and interaction of various social and economic actors (Kjellberg & Helgesson, 2007). Technology both influences and is influenced by these diverse actors (Akaka & Vargo, 2014). A business model illustrates an understanding of how all the actors can best serve themselves through service to other stakeholders in the service ecosystem (Wieland et al., 2017).

From focusing on the best practices of a company, the service ecosystem shifts attention to how institutions are reformed. Institutional processes, such as the maintenance, disruption and change of rules, norms, meanings and symbols, are considered fundamental to technologies, markets and business models, and to enabling and constraining resource integration and value co-creation processes. The service ecosystem perspective guided the ROSE research reported in Lanne et al. (2019). In addition to companies, the ecosystem involves actors such as individuals, universities, associations, unions, governments, competitors, investors and other entities not usually belonging to traditional supply chains (Letaifa, 2014). This perspective provides a comprehensive social and institutional framework to describe business and non-business relationships (Letaifa, 2014; Wieland et al., 2012) and thus facilitates understanding the performative nature of markets, technologies and business models (Wieland et al., 2017).

For the study by Lanne et al. (2019), managers of 10 companies in the health and care technology business in Finland were interviewed. The qualitative interview data were supplemented by quantitative data from an online survey concerning perspectives of different stakeholders concerning care robots in Finland (for further information on the survey, please see the innovation ecosystem sections). These data included results from 13 companies in the field of robotics or care. In addition, during the interviews, the informants filled in a short Likert-type scale questionnaire about the importance of different application fields for care robotics. Content analysis was used to analyze the interview data. A framework presenting the service ecosystem perspective (Wieland et al., 2017; Vargo & Lusch, 2016) guided the data analysis. In order to draw conclusions on the service ecosystem in the context of care robots, the findings of the interview analysis and the online survey were compared with the service ecosystem perspective (Figure 7).

4.1.2 Issues affecting business opportunities related to care robots

The interview and survey results highlighted some important issues affecting business opportunities related to care robots. Five themes were identified from the interview data – perceptions related to end-users; potential of care robots; co-creation and collaboration; demonstrating benefits; and societal and operational framework. The themes revealed a link to value creation and the service ecosystem perspective through interactions of markets, technologies and business models (see Figure 7). The results of the survey also supported the interview findings by emphasizing the relation of the societal framework and markets through funding models, legislation and innovation policy. In order to understand service business enablers in the care robot context, promoting and hindering effects on value co-creation were identified from the opinions of the interviewed stakeholders. In the survey, care culture, lack of funding models, legislation, innovation policy, resistance to change and fear towards robots were the most often selected factors that were seen as hindering the introduction of robots in the Finnish welfare services. As to the promoting factors, care culture (again), readiness to change and attitudes of the older persons were the most often selected ones.

Figure 7 presents enabling factors affecting opportunities and challenges from the perspective of the service ecosystem. According to the interviews, the business potential of care robots was recognized especially in care robots supporting older people's independent living, and in tasks where human contact was not substituted by technology. Care robot solutions related to safety and security (such as alarm systems) were considered very important, and a number of other application fields were considered quite important: cleaning, assisted lifting and getting up, physical support for movement (at home), e-health and e-care, outdoor navigation, transportation, communication and rehabilitation. The companies were most interested in robot technologies that are mature and cost-effective, enabling cheap solutions.

Despite the potential of care robotics, and the generally positive attitude towards new technology, most of the interviewees were rather cautious about the new market. Confrontation between care technology and care quality was seen to be hampering the development of solutions that would benefit the various parties involved (older adults, their friends and relatives, caregivers, companies, the society). Opportunities for business-related cooperation were recognized, for example, in platforms and application development. Genuine cooperation between the companies had been difficult to achieve during previous joint research projects. Research institutes were considered to have a strong role in demonstrating the impacts and verifying the benefits of care technology solutions. This activity has an important effect on generating trust within the market.

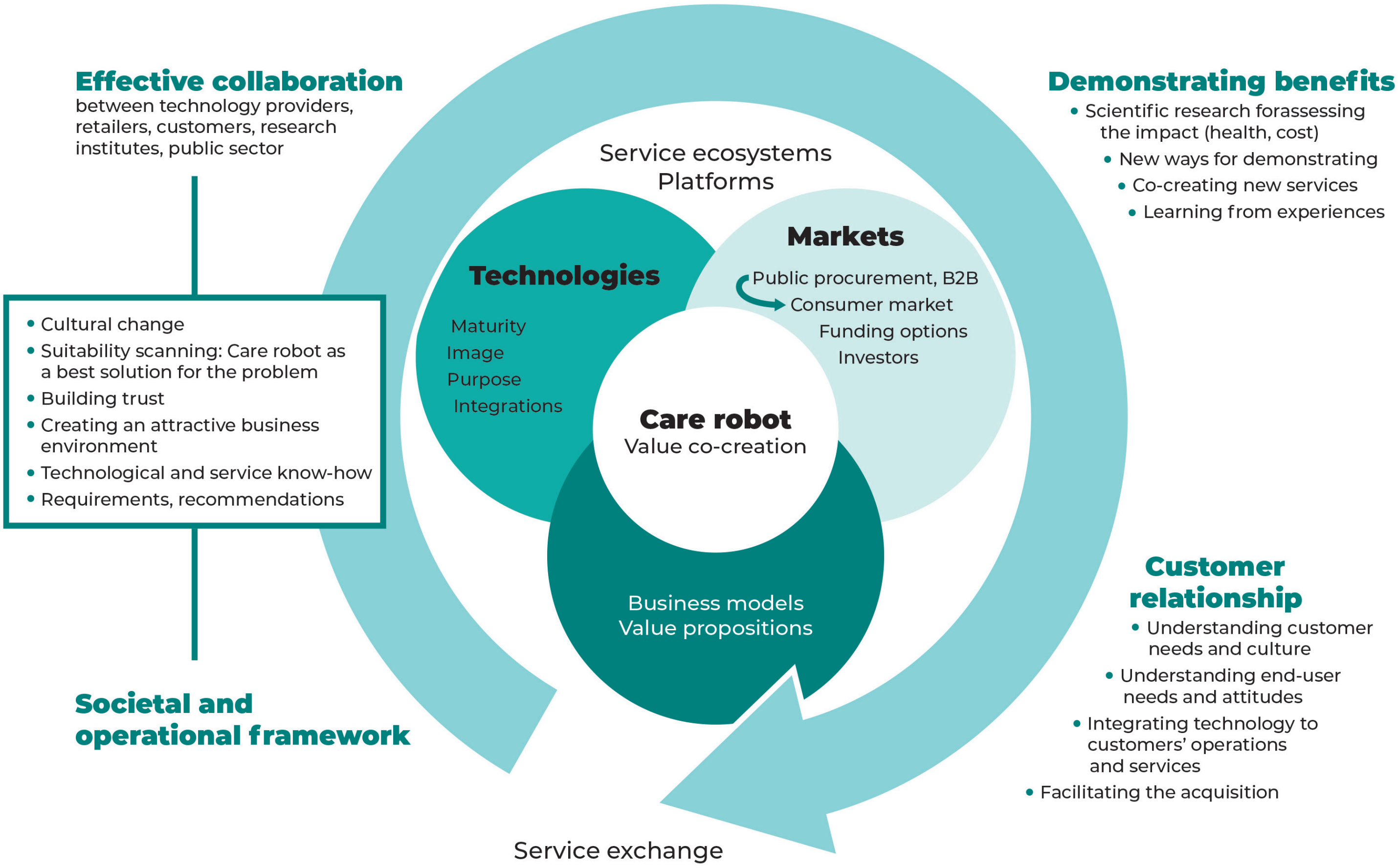


Figure 7 Service business enablers in the care robot context (Lanne et al., 2019)

Certain challenges were identified in the construction of business and the market. First, difficulty in finding the right payer due to the current complexity of the public administration and lack of public customers' technological know-how were recognized. This was assumed to limit the purchasing of the care technology and to hinder the growth of the public-sector market, which also contributes to the consumer market. The second challenge was related to demonstration of the benefits. Companies needed wider-scale scientific research evidence of impact in order to justify technology solutions and build trust in the international markets. Current pilot projects for demonstration were considered too fragmented, small and inadequate. Future innovation policy could play a role in streamlining pilot projects. Lack of objective evidence of the benefits was assumed to hinder penetration into the international markets. More systematic comparison of different technologies; longer periods under review; higher numbers of end-users for testing; regional comparison and more efficient execution of projects were proposed.

Third, the business field was fragmented, and the companies were rather small and pursued their own advantage. This was a challenge for the formation of a service ecosystem that would have more potential in the international markets. Value co-creation with the customers was not very deep, although some companies emphasized the service perspective and a good understanding of the customers' needs, operations and culture. Again, this is an issue in which innovation policy could play a role in the future to unleash the full potential of care robotics and related business.

4.2 The innovation ecosystem

4.2.1 Study of the emerging care robotics innovation ecosystem

In the following, the perspective is shifted towards the wider innovation ecosystem, based on ROSE research reported mainly in Pekkarinen et al. (2019). The innovation ecosystem concept (Adner, 2006; Adner & Kapoor, 2010), drawing upon Moore's (1993) concept of the business ecosystem, has increasingly gained ground in the literature on strategy, innovation and entrepreneurship (de Vasconcelos Gomes et al., 2018; Shaw & Allen, 2018), and in regional development (Rinkinen & Harmaakorpi, 2018). Several scholars still regard the innovation ecosystem as synonymous with the business ecosystem, while others differentiate the two ecosystems (de Vasconcelos Gomes et al., 2018; see also Valkokari, 2015). According to Jackson (2011), the innovation ecosystem models the dynamics of the complex relationships formed between actors or entities whose functional goal is to enable technological development and innovation. The actors include the material resources (funds, equipment, facilities, etc.) and the human capital (students, faculty, staff, industry researchers, industry representatives, etc.) that together make up the institutional entities participating in an ecosystem. Jackson (2011) further considers the innovation ecosystem to comprise two distinct and largely separate economies: the knowledge economy, driven by fundamental research, and the commercial economy, driven by the marketplace.

As in biological ecosystems, each member shares the fate of the whole (Moore, 1993; 2006; Iansiti & Levien, 2004). Due to possible conflicts between the success of an ecosystem and the individual (Nambisan & Baron, 2013), achieving an 'ecosystem mindset' is important. When mapping an ecosystem, one should try to identify the organizations whose futures are most closely intertwined and that share certain dependencies (Iansiti & Levien, 2004). In the ROSE research, this was done when preparing the survey to Finnish stakeholders (Pekkarinen et al., 2019). Ecosystems cross a variety of industries and include several domains (Iansiti & Levien, 2004), and they may also contain independent niches that can be developed within the ecosystem through specialized new ventures (Moore, 2006; Zahra & Nambisan, 2011).

The ecosystem concept has been perceived as having a self-organizing and self-renewing nature. For instance, Peltoniemi and Vuori (2004) stated that if the theory of ecosystems as complex, self-organizing and self-sustaining systems is adhered to, no government intervention should be needed for them to survive in the global market. However, Oh et al. (2016) saw innovation ecosystem as a designed entity instead of an evolved entity, and it has to be noted that the field of care services has special characteristics that highlight the role of government intervention (e.g., Lyttkens et al., 2016). The Finnish public sector has a strong regulatory role, playing simultaneously the roles of service producer and organizer (Ministry of Social Affairs and Health, 2018). With this in mind, it is important to understand which parts of the innovation ecosystem can be engineered and which parts are self-organized or co-evolved (Ritala & Almpanopoulou, 2017). Ritala and Almpanopoulou (2017) suggest that the concept of innovation ecosystem fits market-based initiatives in particular, while other more established concepts could be used to discuss public policy. However, they also note that there are shades of gray between the contexts. This is certainly the case of service robotics; there are both market-driven forces and policy issues that can be noted in the emergence phase. Despite growing interest in innovation ecosystem research, their emergence has barely been studied.

The ROSE research reported in Pekkarinen et al. (2019; see also Tuisku et al., 2017) contributed to filling this gap. The study focused on the dynamics of the emerging care robotics innovation ecosystem in the Finnish welfare services. As innovation ecosystems have both evolutionary nature as well as aspects of purposeful design, the relevant actors, their roles, the accelerators and the barriers were examined by conducting a survey among relevant stakeholders in the innovation ecosystem. An online survey was conducted with a range of Finnish stakeholders (n = 250) including service actors (n = 148) and research and development actors (n = 102). Based on the idea of an innovation ecosystem comprising both producers and users/consumers, the care robotics innovation ecosystem was identified as involving, on one hand, service actors who are responsible of acquiring robots in welfare services (such as municipalities and hospital districts) and, on the other, research and development actors (decision makers, development organizations, research institutes and robot-related firms), whose tasks are related to the development work of robots, from different perspectives. The service actors have more 'hands on' expertise in welfare services than the R&D actors. The responses of the two groups were analyzed with a pairwise t-test.

4.2.2 Towards a purposefully managed and self-evolving innovation ecosystem

The results (Pekkarinen et al., 2019) showed that a variety of stakeholders are needed in the innovation ecosystem (see Figure 9). According to the respondents, the most important groups that should be involved – both in the discussion as well as in the product and service development related to robots – are private persons who use robots in their homes, customers of services that utilize robots, as well as professionals who use robots (see Figure 8). The R&D actors, in particular, emphasized that private persons who use robots in their homes as well as customers of services that utilize robots, should be involved in the discussion and development activities. The responses also indicated the important role of researchers in the public discussion — they are most likely to provide valid information based on empirical knowledge. The R&D actors seemed to think that more stakeholders are needed to take part in the discussion than the service actors did. The service actors had discussed the use of robots in welfare services with fewer stakeholder groups than the R&D actors. However, both groups had discussed the use of robots within their own work community. Overall, collaboration regarding the use of robots in welfare services is still rare. The R&D actors had collaborated significantly more than the service actors.

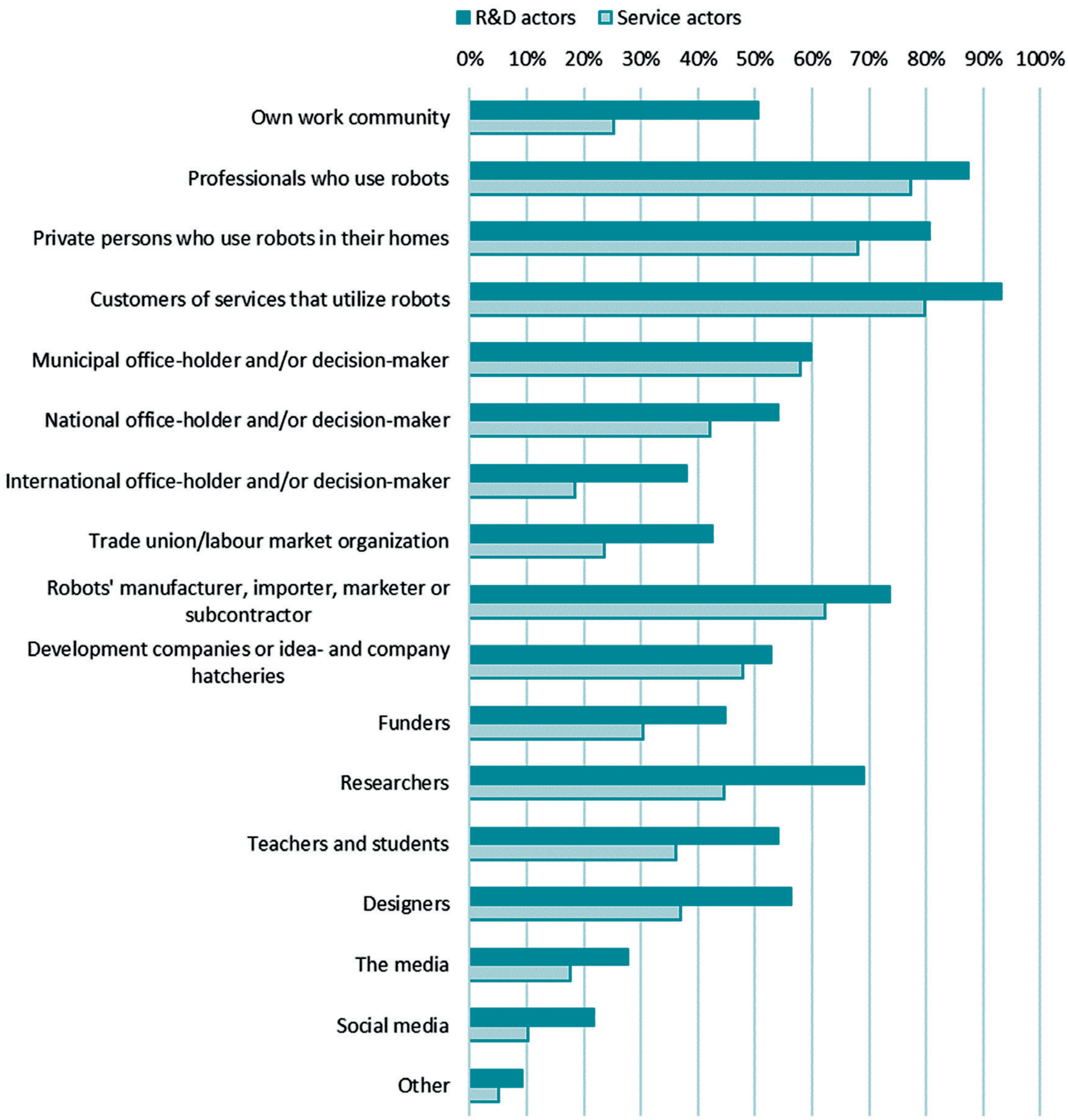


Figure 8 Expected involvement of stakeholders in the development of products and services related to the use of robots (Pekkarinen et al., 2019)

To summarize the results concerning the roles in the innovation ecosystem, the role of micro-level actors, such as colleagues and professional and private robot users, were considered extremely important. The service actors should also play a stronger role in the ecosystem. In particular, the R&D actors seemed to be open to new stakeholders entering the ecosystem and highlighted the importance of collaboration between actors.

The dynamics in the innovation ecosystem seem to be largely based on social and cultural issues. The respondents thought that many factors have the potential to accelerate the introduction of robots into welfare services, but a 'clear winner' could not be found. However, among the R&D actors, the piloting culture – the practice of piloting and experimenting with the products in different environments in Finland – seemed to be considered the most important factor in speeding up the introduction of robots. When piloting, a piece of technology (such as a robot) is used for a short period of time to see how it might fit into the context and what type of tasks it could perform. Such practice makes it possible to anticipate and test the usefulness of the technologies before they are introduced into broader use[23]. The culture of piloting is also an opportunity to increase experience-based knowledge regarding the systemic and human impacts of robot use as well as the resources needed, such as skills and expertise (Kyrki et al., 2015).

According to the survey, three factors seem to have the greatest effect on slowing down the introduction of robots: the care culture, resistance to change and fear of robots. The R&D group suggested two additional factors that seem to hinder the introduction of robots: a lack of funding models for innovation and acquisition, and a lack of domestic robot technology development. To summarize, the culture of piloting in Finland is accelerating the introduction of robotics and ecosystem growth in the society, but factors such as fears and resistance to change are hindering its development. The hindering factors are largely attitudinal and based on existing path-dependencies rather than on technological limitations.

According to the results of Pekkarinen et al. (2019), the robotics innovation ecosystem appears to be both 'a target for managerial action' and 'self-evolving', in accordance with what Ritala and Almpanopoulou (2017) called for. The ecosystem is self-evolving related to accelerating and hindering 'forces' as well as mutual collaboration and adjustment between actors, but still it seems that there is a need for purposeful action and management, for instance, in terms of having users participate – and also in terms of policy actions related to, for example, funding instruments (Figure 9).

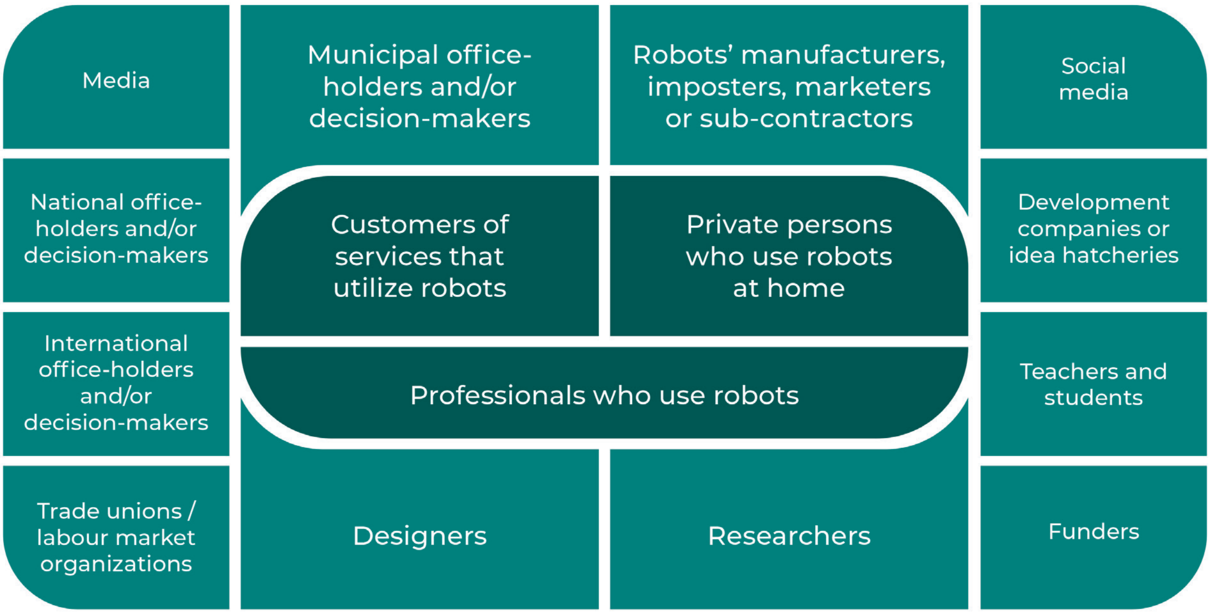


Figure 9 Innovation ecosystem actors from different levels of society, based on the study by Pekkarinen et al. (2019)

[23] Experimental Finland. Piloting and experimenting https://kokeilevasuomi.fi/en/piloting-and-experimenting

Given the strong role of the public sector in Finnish care services, it must – in addition to relevant businesses – be considered an essential part of the care robotics innovation ecosystem. Innovation ecosystem thinking may be characterized as future-oriented. The field of robotics allows space for future business activities that may not yet exist or are only in their early phases (Tuisku et al., 2017). The role of users in the future of care robotics in Finland is of utmost importance, as much depends on their acceptance and skills.

The study by Pekkarinen et al. (2019) concerned the birth-phase of the ecosystem, however, and therefore cannot foresee or predict its future dynamics, such as which actors' roles will become important in the later phases of the ecosystem development. It is evident that robotics will become increasingly important in all fields of society and that the studied innovation ecosystem will continue to grow. The topic is already taken seriously at the national level in line with the emergence and operations of the Hyteairo programme (Finnish Institute for Health and Welfare, 2020).

4.3 Other perspectives related to ecosystem thinking

Impact assessment – conducted on a continuous basis and early enough, not just as ex-post evaluation – is an essential element from the perspective of innovation ecosystem development, because careful impact assessment may unveil invisible or seemingly irrelevant processes and stakeholders that should be considered in corrective actions, when negative impacts are observed. Implementation research itself needs to be highlighted, as it provides a longer-term view of robot integration challenges than pilots. Opportunities for implementation research have been slowly increasing in Finland (e.g., the ROSE study reported in Melkas et al., 2020).

In addition to early implementation efforts, quite many pilots have been and are being implemented in Finland. Piloting is often seen as a process that, at best, starts with collection of information and ends with evaluation. Evaluation seeks to find out factual information on, for example, users' experiences concerning benefits, challenges and usability of the robot. When considering the innovation ecosystem perspective, integration of robotics into welfare services should be approached – rather than as a process – as 'a co-creative piloting and implementation culture' within the wide ecosystem. In such a culture, the whole of care (the architecture, processes, actions and ways of thinking) – into which robots are being brought – would be emphasized. This concerns the different levels – micro, meso and macro.

In such a culture, the focus would be on paying close attention to what takes place and emerges during the pilots and implementation, in particular; what kind of dynamics occur and who is truly involved in the co-creation (the users, notably). From the perspective of managing such a cross-cutting culture and the innovation ecosystem, it is essential to understand and utilize such focused knowledge by, for example, strengthening positive issues and weakening or eliminating negative ones. Micro- and meso-level studies already provide many lessons to learn from. Management of a co-creative piloting and implementation culture is obviously demanding because the co-creation is not only about direct interaction between diverse people, but also about factors such as professional identities, managerial practices, 'states of mind', feelings, responsibilities, and future horizons. Practicing such a co-creative culture should essentially include participatory methods.

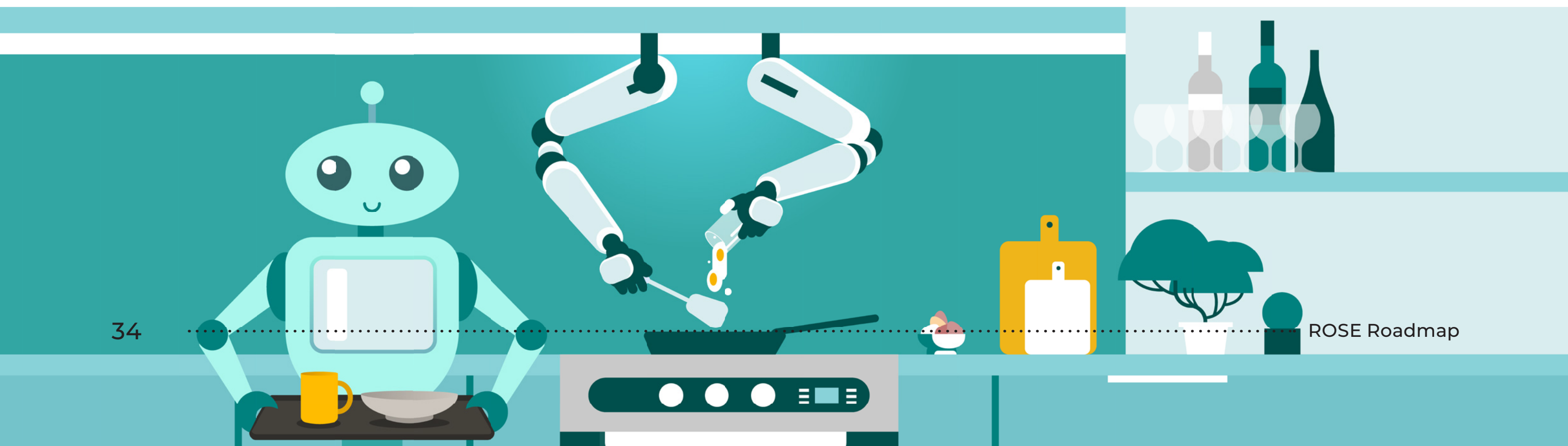
The ROSE studies have focused on all the different levels that are essential in innovation ecosystem development and success. According to interviews with micro-, meso- and macro-level stakeholders, knowledge-related issues, such as the value of knowledge brokers – actors who 'translate' diverse stakeholders' different 'languages' for the common good – also require attention in ecosystem development (Parjanen et al., forthcoming; see also Tuisku et al., 2019, on the public opinion). Defining the ecosystem boundaries is generally challenging, and there might even be conflicts between the ecosystem's and the individual members' successes. The creation of an 'ecosystem mindset' continues to be important for the field of robotics in Finnish welfare services (see the first ROSE roadmap, 2017). In the best case scenario, the entire ecosystem perspective will be carefully considered also when making strategic choices and decisions within one organization.

Especially from a future-oriented perspective, ecosystem thinking may be developed with the help of education. In addition to increasing 'hard' technical competences, education should cover issues related to practical use of robots as well as work life changes brought about by robot use. New abilities to process and analyze data; knowledge about data and cyber security, automation and industrial management; understanding about social dimensions of robot technology, operational logic and principles of robots as well as usability; skills in design of user interfaces and robotic devices, and knowledge about ethical issues and risks related to robotics were called for in the national survey. Educational institutions should build multi-disciplinary programs that combine technical and welfare-related issues. Those studying social and health care should gain certain technical competences, while those studying technology should gain competences in psychology and behavioral sciences. Holistic understanding was emphasized by the survey respondents; multi-sector and multi-professional skills and knowledge as well as openness can be advanced by education. (Tuisku et al., 2017; Pekkarinen et al., 2019)

Interviews at micro-, meso- and macro-levels (see 3.5) confirmed the importance of integration of care robot related issues into the education of future care professionals, early in their studies (Melkas et al., forthcoming). The interviewees emphasized, for example, that basic education, at all levels of social and health care, should always include education on care robotics. According to them, care robotics is not a separate issue to be discussed in some special courses – as it is nowadays – but it must be integrated into everything that is taught: 'If the Swedish language is taught, then the relevant concepts in Swedish are taught, and if care work is taught, or care for some particular illnesses, then the opportunities [of robotics] there or in that illness should be taught'. Continuing education as well as continuous provision of information to various societal stakeholders must not be forgotten, either. The interviewees brought up good examples of educational pilots in vocational education, of cross-disciplinary programs, but noted that new occupations and occupational groups emerge, which increases the need to understand each other's work and the big picture. As technology may become outdated, basic education in social and health care should not settle for teaching the use of individual devices but create capabilities to see and develop robot use as a wider issue. (Melkas et al., forthcoming) Educational policies and contents are important steps towards improving ecosystem thinking.

4.4 Conclusions

Wider and deeper understanding of the societal and systemic levels related to robots in welfare services is of vital importance to perceive the whole of the larger socio-technical transition. Several ecosystem concepts exist, but ecosystem thinking in general is the key. In the ROSE research on the service ecosystem perspective (reported in Lanne et al., 2019), business opportunities related to care robots were recognized, but several challenges were also unveiled. Current pilot projects for demonstration were considered too fragmented and inadequate; streamlining pilot projects and objective evidence of the benefits of robots were called for. The business field is still fragmented with rather small companies that pursue their own advantage, according to the respondents. This is a challenge for the formation of a service ecosystem that would have more potential in the international markets. The importance of the user focus was emphasized. In the ROSE research on the innovation ecosystem perspective (Pekkarinen et al., 2019), again, the examination of the dynamics of the emerging care robotics innovation ecosystem in the Finnish welfare services confirmed the need for involving a wide variety of stakeholders. Collaboration regarding the use of robots in welfare services is still rare. The service actors should play a stronger role in the innovation ecosystem. The ecosystem is self-evolving related to various 'forces' accelerating and hindering the use of robots as well as actors' mutual collaboration, but purposeful action and management are also needed, for instance, to have users participate. Continuous and early impact assessment (e.g., the ROSE study reported in Melkas et al., 2020) is an essential element for the innovation ecosystem development. Implementation research needs attention, as it provides a longer-term view of robot integration challenges than pilots. Integration of robotics into welfare services should be approached as 'co-creative piloting and implementation culture'. Moreover, especially from a future-oriented perspective, educational policies and contents are important steps towards improving ecosystem thinking, as is taking knowledge-related issues, such as knowledge brokerage, into account.



5 ETHICAL, CRITICAL AND PHILOSOPHICAL VIEWS ON CARE ROBOTS

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This chapter discusses ethical, critical and philosophical questions concerning robots in care for older adults. We analyze the impact that care robots might have on human dignity, or more specifically on the sense of autonomy or loneliness of older adults that live in assisted living facilities. We take a critical look at how media and robot ethics view care robots and analyze robot embodiment and cognition as well as how robot-human interaction differs from human sociality.

5.1 Ethical questions concerning human dignity, autonomy and loneliness

5.1.1 Human dignity

Robot-human interaction touches several central human values that come to fore particularly strongly in the context of older people. Human dignity is perhaps the most central one. Is it under threat? Can robotic care support or challenge human dignity in care for older people, and how?

The answer will depend on whether it is robot-based, robot-assisted, or teleoperated care that is at stake (see Chapter 2.2). Further, the realizations of human dignity must be distinguished from the demands and duties that human dignity gives rise to. The demands to respect humans are based on human dignity and the inalienable high and equal moral standing that everyone has. For human moral agents, these demands take the form of negative and positive duties. For robots, they arguably take the form of corresponding ought-to-be norms. The realizations of dignity consist in variable responses to these demands, by oneself, by others, and by society at large.

The article Demands of dignity in robotic care: Recognizing vulnerability, agency, and subjectivity in robot-based, robot-assisted, and teleoperated elderly care (Laitinen et al., 2019) examines how robot-based, robot-assisted, and teleoperated care can amount to realizations of dignity. The varieties of robotic care can, in different ways, respond to the demands of dignity and recognize humans as vulnerable beings with needs, as autonomous agents, and as rational subjects of experience, emotion, and thought. The main ways in which robots can be a threat to humans is that they harm or injure people, or prevent them from fulfilling their needs, or inhibit or leave unsupported people's autonomous agency or cognition. For example, teleoperated care cannot necessarily provide equally good human contact as physical presence in the same space, and some technologies are restricted to communication. Therefore, they contribute to fewer sensuous aspects of wellbeing than human contact. Robot-based care cannot provide real recognition and communication and can to that extent amount to neglect. Robot-assisted care may also risk physical injury or objectification of the patient. On the other hand, robots can arguably support the satisfaction of human needs, and aid and support people's autonomous agency and cognition in different ways. Some of them are summed up in Table 3; for discussion see (Laitinen et al., 2019).

Table 3 Realizations of dignity in robotic care, regarding vulnerability, agency and cognition (Laitinen et al., 2019, 378-379)

CONCERN FOR → / DIGNITY REALIZED IN ↓	VULNERABILITY AND NEEDS	AGENCY	EMOTION AND COGNITION
THE INALIENABLE STATUS	(negative duty) not harming others; and (positive duty) taking due care of human needs and protecting vulnerabilities	(negative duty) not blocking people's autonomous agency; and (positive duty) aiding and supporting people's autonomous agency.	(negative duty) not blocking people's rational thinking and subjectivity; and (positive duty) supporting people as thinkers and subjects of experience
OWN ACTION (ROBOT-ASSISTED SELF-CARE)	**Positive:** Robotic assistance for protection of safety in one's own activity. **Violation:** self-injury in using robots. **Neglect:** neglect of one's needs in one's own action.	**Positive:** Increasing physical, agentic capabilities. **Violation:** (robot-assisted) disregard for one's dignity in one's action. **Neglect:** neglect of one's (future) needs in one's own action.	**Positive:** Increasing cognitive capacities. **Violation:** (robot-assisted) disregard for one's dignity in one's action. **Neglect:** neglect of one's (cognitive) needs in one's own action.
ROBOT-BASED "INTERACTION" IN CARE	**Positive:** needs met. **Violation:** risk of injury. **Neglect:** cannot provide human contact for social needs.	**Positive:** make more capable, strengthen and motivate. **Violation:** risk of disability. **Neglect:** cannot provide real interaction.	**Positive:** make more capable, challenge and stimulate. **Violate:** risk of disability. **Neglect:** cannot provide real recognition and communication.
ROBOT-ASSISTED INTERACTION IN CARE	**Positive:** helping a nurse treat a person safely. **Violation:** nurse causing pain or anxiety to a person by robot use.[24] **Neglect:** sometimes may not provide human contact for social needs.	**Positive:** supporting a person's own participation in treatments. **Violation:** preventing a person's own participation by robot use. **Neglect:** sometimes may not provide real interaction.	**Positive:** robot taking care of hard work (e.g. lifting) enables nurses to concentrate on emotional needs of a person. **Violation:** objectification of a person by robot use. **Neglect:** sometimes may not provide real recognition.
TELEOPERATED INTERACTION IN CARE	**Positive:** client needs met with technological solutions. **Violation:** possible injury and insult via teleoperation. **Neglect:** cannot provide equally good human contact; some technologies restricted to communication, fewer aspects of wellbeing (e.g. smell, general view of an apartment) may be recognized.	**Positive:** supporting agency by strengthening and motivating. **Violation:** possible violations of autonomy via teleoperation. **Neglect:** cannot provide equally embodied interaction; mere instructions instead of action.	**Positive:** enables meaningful conversations for the lonely. **Violation:** possible denial of cognitive autonomy in teleoperated interaction. **Neglect:** sometimes may not provide real recognition; lack of comprehensive human interaction.
BACKGROUND CONDITIONS OF LIVING	Smarter technology may be better, but may be more dangerous?	Smarter technology may be better, but will it require too much physically?	Smarter technology may be better, but will it dumb us down? Will it require too much cognitively?

[24] Human nurses are better at interpreting movements, gestures, and facial expressions when patients are feeling uncomfortable, even if patients cannot say it out loud. For more, see Parviainen & Pirhonen (2017).

5.1.2 Sense of autonomy

Another central value in the lives of older adults that robots might make a difference to is personal autonomy. Assisted living (AL) is the fastest growing form of older adults' long-term care, and resident autonomy has become the watchword for good care. Pirhonen and colleagues (2019) have analyzed the potential effects of care robotics on the sense of autonomy of older people in AL. Three aspects of the residents' sense of autonomy are of particular interest: (a) interaction-based sense of autonomy, (b) coping-based sense of autonomy, and (c) potential-based sense of autonomy.

The *interaction-based sense of autonomy* can conceivably be supported by different kinds of robots that could widen the residents' space of daily movements. In addition to concrete help, assistive robots can make residents feel less dependent on the staff and formal care. Social robots could, in principle, become 'allies' to the residents, and their presence in itself has been found to have a positive effect on older people (Sorell & Draper, 2014). Telepresence robots, on the other hand, may bring relatives and friends outside the facility closer and thus empower the residents and make them feel more autonomous.

The coping-based sense of autonomy can conceivably be strengthened by assistive robots, such as exoskeletons, which can sustain the residents' capacities. Robots may be pictured as hi-tech aids to older adults, helping them accomplish multiple tasks that would otherwise pose severe challenges to their functional abilities. With a little help from a robot, the residents may be able to carry on with their life-long hobbies for extended periods or perhaps even start new ones.

Regarding the potential-based sense of autonomy, robots can conceivably help older adult maintain their normal future expectations of autonomy despite deterioration of their abilities. Robots can work as guarantors of their future actions: if an older adult loses her/his ability to achieve a goal independently, a robot may work as an extension of her/his agency and secure the accomplishment in the future (c.f. Perkins et al., 2012; Pirhonen & Pietilä, 2016). Robots may thus create capabilities for the residents.

In AL facilities, the majority of residents suffer from dementing illnesses (Matthews & Dening, 2002; Noro & Alastalo, 2014; Wolinsky et al., 1993). The more severe the cognitive impairment is, the fewer opportunities the person has to use robots. The vast majority of residents will eventually lose the ability to make use of robotics. Optimally, robot applications would be adopted in early ageing when cognitive capability and resources to learn and adapt to new technology are good – when the person is still living independently at home so that the person with a dementing illness could postpone the decrease of personal autonomy for as long as possible with the robot.

5.1.3 Loneliness

The flipside of autonomy may be loneliness. Pirhonen et al. (2020) have examined emotional and social loneliness of older people in assisted living facilities. Their study draws on Robert Weiss' (1973) division of relational functions: attachment, social integration, opportunity for nurturance, reassurance of worth, sense of reliable alliance, and guidance in stressful situations, and on a novel distinction between direct and indirect social robots (Pirhonen et al., 2020). They use the term 'direct social robots' to cover humanoid robots and therapeutic robots whose purpose is to interact with people in a human-like way in order to develop close and effective interactions between the robot and the human for the sake of interaction itself. In addition, they refer to equipment designed to link people together, such as telepresence robots and sophisticated moving aids (such as exoskeletons and robot wheelchairs), as 'indirect social robots.' In other words, direct social robots are designed to socialize with people, whereas indirect social robots help people bond with each other.

Pirhonen and his colleagues argue that both direct and indirect social robots could tackle the loneliness of AL residents, as shown in Table 4, highlighting the future opportunities. The table also features specific ethical concerns related to social robots for loneliness.

Table 4 Current and potential outcomes of social robots in AL, with ethical concerns acknowledged (Pirhonen et al., 2020, 7)

	Emotional loneliness				**Social loneliness**		**Main robot type -specific ethical concerns**
	Relational functions				**Relational functions**		
	Opportunities for nurturance	*Reassurance of worth*	*Sense of reliable alliance*	*Guidance in stressful situations*	*Attachment*	*Social integration*	
Direct social robots	+ are "something to love" + encourage human interaction	+ address residents with respect **(+)** remember residents' individual details	+ obey residents' instructions **(+)** may be companions	+ may act as calming instructors **(+)** may be companions	+ provide company and activities + provide opportunities for attachment	**(+)** may be companions	**Deception when the line between humans and robots is blurred**
Indirect social robots	+ bring loved ones closer virtually + help reaching other people physically	+ help maintaining sense of being capable (moving aids)	+ maintain sense of belonging to groups outside the facility virtually and physically	+ offer virtual comfort from loved ones	+ help reaching other people virtually and physically	+ help reaching other people virtually and physically	**Objectification when elderly care is "left to machines"**
Common ethical concern	**Risk of lacking live human contact**						

+ = current outcomes / **(+)** = in future, mainly

When aiming to tackle a complex social issue such as loneliness, it is important to note that simple solutions are problematic, perhaps even impossible to find. Loneliness is influenced not only by the physical environment and individual situations, but also by the ways older people and their needs are perceived in society. Arguably, as noted by Burholt et al. (2016), recommendations arising from meta-analyses are often skewed because the medical understanding of loneliness dominates the conversation, and studies focusing on decreasing loneliness as the primary outcome are prioritized. What is at stake is a highly complicated human mosaic; empathy and appreciation must be used as the basis for meaningful, informed technology–based assistance (see also Rogers & Mitzner, 2017).

5.2 Critical view on robot hype and robot ethics

Twenty years ago, robotics guru Joseph Engelberger (2000) forecasted that a multitasking robot caregiver for old people would be developed, manufactured and marketed soon. Around 1995 he was travelling the world to motivate research teams to embark on his mission towards designing the 'Elderly Care Giver', a multitasking personal robot assistant for everyday tasks (Engelberger, 1997; Pransky, 2018). Following Engelberger's vision several prototypes or research platforms have being developed, including Fraunhofer IPA's care robot platform called Care-O-Bot, the Hector mobile assistive robot prototype and the Hobbit robot prototype[25]. It seems that neither of these robot prototypes have so far led to a commercial launch of a product beyond research purposes. One of the exceptions is the Wakamaru domestic robot which was launched by Mitsubishi in 2005. Unfortunately, the Mitsubishi company received no more than a few dozen orders and failed to sell a single robot.

Nevertheless, at the end of 2010's, media hype around care robots for older adults still strongly resonated with Engelberger's visionary mission (Van Aerschot & Parviainen, 2020). The media have played a pivotal role in giving publicity to care robot developments to advance their speculations about the future of humanoid robots in care (Parviainen & Coeckelbergh, 2020). For instance, *The Guardian*, a widely respected newspaper, reported in 2016 'how a robot could be grandma's new carer'.[26] In 2017, the BBC News declared how academics say that 'robots could help solve the social care crisis'.[27] In 2018 *The Guardian* argued that 'Japan lays groundwork for boom in robot carers'.[28] The illustrated photo within the story of *The Guardian* in 2018 used a Japanese robot prototype 'Robear', lifting a woman for a demonstration at RIKEN-TRI in Nagoya. The robot prototype was developed to transfer frail patients from a wheelchair to a bed or a bath. However, what the newspaper failed to mention was that RIKEN-TRI and its Center for Human-Interactive Robot Research (RTC) finished its scheduled research term and dissolved at the end of March 2015.[29] This implies that the development of the robot had already been suspended three years earlier before *The Guardian*'s item so the lifting robot would never be launched on the market as such.

The promises of Engelberger's robot vision on multitasking personal robot assistant have not been fulfilled over the past 25 years. Available care robots have not been proved to truly help with maintaining older people's independence or improving their well-being as Engelberger envisioned. One of the main technical bottlenecks in developing useful robots for home care and nursing homes is the lack of sophisticated robotic limbs that could help older people with dressing, bathing and toileting. One of the problems is related to safety criteria set for health technology in which all kind of moving or lifting robotic limbs are inspected for risks of injury to vulnerable people. The problems in developing the robot's kinematic capabilities to meet the safety standards of multitasking household robots have led designers to simplify their goals. Partially due to strict safety criteria, designers have turned either to develop entertaining social robots or to define precise simple functioning without direct physical contact with human beings.

Social robots, such as humanoid robots Zora/Nao or Pepper, cannot yet conduct physical and concrete care tasks including dressing, bathing and toileting. Still, *The Guardian*, in reporting in 2016 'how a robot could be grandma's new carer', used the Pepper robot as illustration. This robot type does not have the fine motor ability to assist older people in their daily activities, and using the Pepper robot in such illustrations creates a false impression of the care robot's ability. Another example of misleading information about the capabilities of today's care robots is the use of robot prototypes as illustrations, as *The Guardian* did in 2018. The item argued that 'Japan lays groundwork for boom in robot carers', using perhaps accidentally the photo of the suspended robot project.

[25] The Hector robot is a mobile assistive robot and smart home interface funded by the EU Seventh Framework Program. The goal of the Hobbit project, funded by the EU in 2011–2014 was 'to advance towards a robot solution that will enhance wellness and quality of life for seniors, and enhance their ability to live independently for longer at their homes.' http://hobbit.acin. tuwien.ac.at/

[26] https://www.theguardian.com/technology/2016/nov/06/robot-could-be-grandmas-new-care-assistant

[27] https://www.bbc.com/news/education-38770516

[28] https://www.theguardian.com/world/2018/feb/06/japan-robots-will-care-for-80-of-elderly-by-2020

[29] http://rtc.nagoya.riken.jp/index-e.html

In a strict view, providing highly speculative information on care robots could be even called *misinformation* if the audience judged it to be a credible image of the future. From the epistemological perspective, misinformation is understood as false or inaccurate information that is communicated regardless of the intention to deceive (O'Connor & Weatherall, 2019). Scientists and research teams that send press releases of their robot experimentations can create intentionally or unintentionally high expectations of care robots. They can be partly blamed for strengthening skewed images of the capabilities of care robots. In transmitting news on robot experiments, journalists should make it clearer that robot prototypes may never end up in consumer use. It can be considered as misleading to present multitasking and autonomous robots as a solution for responding to care needs of older population when the available devices are mostly interactive robotic pets, automatic medicine dispensers or floor-cleaners which as such have a limited role in solving the societal-level social and economic problems related to organizing care (Van Aerschot & Parviainen, 2020).

One of the misconceptions often associated with care robots is that the low implementation of robots in care is primarily due to negative user attitudes. It rather seems that a central problem is that there are very few care robot types available on the market. This presumption is supported by the facts of the development and sales figures of the worldwide service robotics market in recent years. Although there are no separate statistics on care robotics, by looking at the value of the world trade in service robots for personal and domestic use, we can outline the volume of robot production in care for older people (IFR, 2020). According to the International Federation of Robotics' (IFR) recent report, the worldwide sales of assistance robots for older adults or handicapped persons was only 91 million U.S. dollars in 2019 (IFR Press Release, 2020). For instance, the value of Finland's exports of health technology products alone was 2,400 million [2.4 billion] EUR in 2019.[30]

The challenges caused by the small number of care robots in active use are clearly visible in experiments and the research design of care robots for the old people. It is likely that research teams would acquire robots for experiments if affordable and functional equipment were available. However, it seems that many empirical studies conducted on care robotics have focused on examining end users' preferences and acceptance of robots, and asked respondents' attitudes towards robotics. Due to the small number of care robots in private homes or nursing homes, many researchers utilize pictures of robots, narratives, audio–video material of robots and robot prototypes to elicit respondents' opinions of care robots (e.g., Hall et al., 2017; Khosla et al., 2017; Smith & Anderson, 2017). Empirical results concerning the benefits or disadvantages of care robots can be thus considered speculative to some extent. Therefore, their overall impact on the well-being of older people and the work conditions of nurses cannot be entirely foreseen. It is important to continue studying care robots in various settings, so that knowledge of their use and impact will accumulate little by little as the technology gets more mature and is used more widely and for different purposes.

Lack of practical experience with care robots and problems with empirical research are also evident in the field called 'roboethics'. The novel research field of roboethics in elderly care has arisen from concerns over the effects and impacts of robot care on older people in the future. Some of this work explores the principles and guidelines of roboethics in general, while most scholars examine issues of dignity and autonomy as well as the fundamental care values such as attentiveness, responsibility, competence and reciprocity in care for older people. The ethical discussions have addressed the expected (speculative) positive and negative aspects of care robotics: the potential for becoming socially isolated, risks of ageist discrimination, and of losing or gaining one's autonomy or opportunities for self-growth. Guidelines to steer the design and development of care robots in the future have been published to consider, for example, the care conditions under which robots should be used or not be used.

In the field of roboethics, the sustainability issues of producing new care technologies have been considered rather narrowly. Considerations should include ecological issues of producing new care technologies, such as energy consumption and electronic waste, inequality between poor and wealthy people regarding expensive equipment, questions of national aging policies related to care robotics, and legal issues of safety regulations on care robotics. Even when the reflections on care robots include ethical theories of human care, robot ethicists rarely take a stand on how the care as a whole should be organized with or without devices, or how limited resources should be allocated

[30] https://healthtech.teknologiateollisuus.fi/fi/terveysteknologia/vientitilastot/terveysteknologian-tuoteviennin-kasvu-jatkui-vahvana-vuonna-2019

to provide sufficient care for all citizens. In addition, robot ethicists have rarely been interested steering economic, ideological and political interests behind advancing R&D initiatives. Presently it seems unclear whether robot ethicists should provide speculative guidelines and principles for the imaginary future of the care robots, or whether their objective is to find ethically and socially sustainable solutions which enhance the well-being, good quality care and equality of older people resulting in reducing care poverty and loneliness with or without robots.

5.3 Philosophical questions about robot embodiment, sociality, cognition and morality

Some philosophical questions that robotics raise concern human bodies and robot bodies rather than ethics: human experiences of human and robot bodies, the real or simulated sociality between humans and robots, and the possibility of robots being able to think, or act on moral principles, or be responsible agents.

The interactive capabilities of companion robots are a combination of various aspects that creates the impression of liveliness. This view is based on a field study in nursing homes where the Zora robot was used as a companion robot as part of the ROSE project (Parviainen et al., 2019). The impression of aliveness of the robot body is the result of a combination of four aspects: 1) material ingredients (plastic, lights, etc.), 2) robot morphology, 3) animate movements guided by software programs and 4) storytelling and narratives created by users. These results suggest that narratives on the affective states of robots, such as sleepiness or becoming frightened, trigger the users' empathic and caring feelings towards the robot.

As another example, Laitinen (2018) examines whether feedback from robots, which an interlocutor does not regard as minded persons, could enhance the interlocutor's self-esteem or count as genuine recognition. Many people accept that a fully 'personifying' stance concerning robots would be a category mistake: robots are not persons. Would such people care about feedback from robots? The paper argues that social robots may form a new category, new 'social grammar', with genuine normative expectations and experiences. Recognition from other persons is central to the social basis of self-esteem. Feedback from robots is an interesting combination of objective non-social feedback and simulated recognition: robots can arguably, and perhaps surprisingly, send real recognitive messages that matter to people, even when they themselves are not recognizers.

Laitinen (2019, in Finnish) relates the seemingly empirical question about whether non-living machines can think, and deeper philosophical 'theories of everything'. Scientific worldview may give a different answer than a commonsensical worldview. One task of philosophy is to form a coherent picture of these two worldviews. Thus, a seemingly empirical question about robots takes us to one of the deepest philosophical questions relatively quickly. One such deep question, tackled in Laitinen's (2019b) 'What principles for moral machines', concerns the nature of moral principles. Understanding the nature of moral principles lays bare what is at stake in the (unabashedly Utopian) attempts to build machines that could give useful advice for humans in moral matters. Only if robots could think or act for moral reasons, could they bear responsibility for their actions. Laitinen (2020) addresses the question of whether robots or self-driving cars will create a 'responsibility vacuum' if they are self-moving, but not rational or autonomous in any demanding sense. The answer defended is that it is humans who bear the responsibility for any technology, and any dreams and future visions about machine capabilities should not distort that basic insight.

5.4 Conclusions

The results of the ethical analyses concerning the impact of robots on human dignity, autonomy and loneliness are encouraging. Robots could conceivably strengthen the sense of autonomy in multiple ways. Different types of robots could widen the residents' space of daily movements, sustain their capacities, and help them maintain and even create future expectations. Social robots could conceivably tackle both emotional and social loneliness in assisted living by empowering people to engage in different forms of social interaction inside and outside the facility. However, robots may also pose a threat to autonomy, and the ethical concerns of objectification, lack of human contact, and deception need to be thoroughly considered when implementing social robots in care for frail older people. In addition to dignity, autonomy and loneliness, further ethical concerns include fairness, which has become very relevant in the context of algorithms, AI and robots (see Sahlgren & Laitinen, 2020; Sahlgren, 2020), and responsibility (Laitinen, 2020).

Although ethical analysis and empirical evidence from actual human users and other stakeholders (see Chapter 3) both suggest that robots have potential in care for older adults, care robotics is still unable to meet its high expectations. The image of robots presented in media has a role in those expectations, and it can be misleading when considering the real capabilities of state-of-the-art robots. Scientists too can support this false image in their dissemination. Reported robot prototypes may never end up in mass production or consumer use. The nondeployment of robots in care may be less a question of negative user attitudes and more of the fact that there are only a few feasible solutions available. Empirical knowledge of the pros and cons of care robots is still meagre, and it is difficult to draw firm conclusions about their ethical impacts. Robot ethics provide guidelines on how care robots should be ethically used in the future, but all in all, the most important thing to consider is how human care should be organized ethically and sustainably, with or without robots.

6 TECHNICAL OPPORTUNITIES AND CHALLENGES

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From a technological viewpoint, robotics is not yet mature enough for welfare services or for supporting independent life. In Chapter 3, we described pilots and implementations of robot applications in care settings. Most of these implementations were related to various technical challenges. They could relate to the robot's limited functionalities, user interaction or the robot's general ability to adapt to the dynamics of a real use environment with real, non-expert users. Some applications function quite well, but they can only be used for limited tasks (e.g., logistics, dispensing medicine). General-purpose solutions do not exist.

In this chapter, we will give an overview of what the present technical opportunities and central challenges are. We will also describe the restrictions of robotics in interaction with humans and as part of care work in the applications areas that have been studied in the ROSE project. We will make predictions of what we expect to be realistic in five to ten years.

6.1 Requirements for robots in care

6.1.1 Autonomously navigating mobile robots

In recent years, we have seen incredible breakthroughs in computer vision and control. When considering mobile robotic platforms, these breakthroughs have led to new capabilities in sensing (semantic object detection, people recognition, and tracking) and mobility (move in different environments and reacting to unpredicted circumstances with high reliability). For example, robots can safely navigate human-populated structured environments such as hospitals for internal logistics applications.

However, the combination of sensing and mobility has not yet translated into an increased ability for mobile platforms to solve high-level tasks or be useful for general purposes. These tasks would require more natural human-robot interaction or complex mobile manipulation capabilities, which are beyond the state-of-the-art. The main bottleneck preventing this is how this newly available richer environment information is represented and processed by robots. We have seen efforts recently directed toward improving capabilities like safety and autonomy by targeting the problem of environment representation (Lundell et al., 2018, Verdoja et al., 2019), but a more general and advanced framework for mapping rich representations is still needed to achieve human-like environment understanding. The current frameworks for environment representation and spatial knowledge extraction are insufficient to address these challenges (Zaenker et al., 2020; Verdoja & Kyrki, 2020). Bridging the gap between sensing and planning is an area where future research efforts in robotic mobility need to focus.

6.1.2 Socially interactive robots

Robots' capabilities to interact with humans are central to social robotics applications. Speech recognition is a central HRI capability, and it has recently advanced to a level where recognition of entire sentences of natural language is viable when the recorded audio is relatively noise free. However, many real-life environments such as hospital wards are noisy and such situations still pose a major challenge due to multiple speakers talking simultaneously. This is a major challenge to current systems. Moreover, the current systems in operation are primarily based on scripted interactions which limits their use as general purpose conversational agents. Thus, even if a system can fully transcribe speech, it may have no grasp of its semantic meaning or context.

An effective social communication requires each participant to have some form of understanding, a model, of their conversation partner. At present, robots' models of their human partners are very limited, but accelerating progress is foreseen in this area. For example, it was recently demonstrated that when a robot queries a human, limiting the cognitive load caused by needlessly difficult questions allows the human to answer both faster and make fewer errors (Racca et al., 2019). Moreover, it was shown that it is possible for the robot to automatically choose questions that are informative and cause a limited cognitive load. Altogether, the development of better models of humans for robots is likely to be a central avenue for more natural and effective human-robot communication.

Humans construct models of the robots with which they interact. This can affect the interaction adversely, if the human assumes that the robot has more advanced cognitive abilities than it does. Because of this, robots need to be *transparent* (Racca & Kyrki, 2018). Humans reflect on robots' cognitive abilities based on their own experiences of interacting with other humans (Racca et al., 2019). They try to understand robots' motives even when there are none in the human sense, as robots only follow their programming without underlying semantic motives. When considering the type of feedback robots give to users, issues of transparency and expressiveness are particularly crucial. Simply communicating information over the robot's internal representations and learning processes does not necessarily convey meaning that helps the human partner (Struckmeier et al., 2019).

6.1.3 Robot manipulators

Simple parallel-jaw grippers are found in many industrial applications but some tasks such as holding a pen cannot be achieved with simple grippers. More complex multi-finger hands such as the Barrett hand have the potential to realize more human-like tasks but are currently limited by their mechanical structure which makes them very fragile and oftentimes heavy. Moreover, they often lack tactile sensing, which hinders many applications such as in-hand manipulation and deciding if the hand is actually grasping an object or not. As of now, the applicability of complex grippers in health and welfare is limited because of their fragile mechanical design. Designing the environment in such a way that parallel-jaw and vacuum gripper are applicable should be the way forward.

Currently, many companies (CovariantAI, Ambidextrous) are utilizing manipulation algorithms to solve industrial tasks such as order picking, putwall and induction. However, they achieve this by constraining and simplifying the environment to only include known objects to be manipulated. Because of this, the robots do not need to reason about obstacles. In more complex environments with unknown objects and obstacles, many manipulation algorithms either fail, or they take a long time to complete the task. To generalize manipulation algorithms to complex environments, robots also need to perceive and model unknown objects in the scene, their shape and sizes, and manipulate them without collisions (Lundell et al., 2019). To date, the applicability of manipulation algorithms in welfare is limited to pharmacies where all objects are well known. In other less structured environments, such as hospitals, robots are not used to manipulate objects due to the limitation of manipulating unknown objects.

6.1.4 Telepresence and remote controlled robots

In the care context, remote controlled robots are currently primarily applicable for robotic telepresence. This is due to the lack of suitable general-purpose robot platforms which would have sufficient manipulation capabilities that could be used remotely and safely in complex environments.

Telepresence technologies have enormous potential to aid humans with certain welfare services, such as remotely visiting homes of patients or self-living older adults (Apostolopoulos et al., 2012; Leeb et al., 2015). The current technology is mature enough to be deployed, but welfare service applications have some special demands that need to be further advanced:

- Telepresence systems must provide clear audio that people with limited hearing can hear over the telepresence device
- The systems must be easier to steer remotely - the preferred steering modality will likely be based on natural language commands such as 'Go forward' or even on semantic level such as 'Go kitchen'
- The privacy and security issues must be solved. How do we ensure that the tele party is allowed into the customer's facilities?

On a positive note, all the technological challenges above are substantially moderate and solvable. There are also telepresence platforms which are ready to be deployed (e.g., Double Robotics). The second item was addressed in the ROSE project (Ainasoja et al., 2019), but due to the urgent demand caused by COVID-19,

6.1.5 General/Multi-purpose platforms

At present, general mobile platforms are not mature enough to fulfil the expectations that welfare and service applications pose on them. While small mobile platforms, such as SoftBank's Nao and Pepper, are finding successful applications as interactive assistants in stations and supermarkets, their abilities are limited to spoken interaction, as their physical interaction capabilities are almost nonexistent. When considering multi-purpose platforms, like PR2 (Willow Garage), TIAGo (PAL Robotics), and Care-O-bot 4 (Mojin Robotics), we see that none of them has found real commercial application yet. These platforms, while able to move and navigate autonomously, safely and somewhat reliably, are still not ready to offer any real interesting experiences to users. Most noticeably, the current hardware is slow to plan arm motions to perform manipulation tasks, and, while the Robot Operating System (ROS) on which most of these robots run, tries to offer easy software interoperability, their software infrastructure is mostly still composed of a mixed array of single-purpose components not integrated properly. Overall, their current software is not on the level required to easily implement user-oriented experiences and programs. Moving forward, improvements in the ROS infrastructure should produce a set of reliable and interoperating libraries for core robotics capabilities, from sensing to manipulation, with the focus of enabling easy implementation of user experiences, which are almost completely absent.

If we envision service robots in human environments, they need to operate for several consecutive hours to be truly valuable. For instance, if a robot needs to charge after one hour of operation, it would require a fleet of robots to complete even mundane tasks such as guiding people around in hospitals or airports. Therefore, we need to make sure robots are made of low power-consuming hardware. Furthermore, relying on cloud computing is a viable possibility for other AI powered devices like IoT and smart gadgets. However, we cannot assume that we can offload to the cloud most of the heavy computation required to give a robot a level of intelligence comparable to that of developing AI components for mobile robots. Reliable internet connectivity might not always be available to robots employed in public spaces. Efforts toward embedded and efficient computing are paramount to the widespread adoption of modern AI for robot intelligence.

6.1.6 Learning robots

Artificial intelligence (AI) is a set of general-purpose methods that allow a machine to make decisions and learn from data. In the context of robots, AI methods can be used to provide various capabilities from perceptual processing, such as recognizing people and objects, to choosing the next action to be performed to achieve a particular goal.

While AI for perception is quite mature and we have seen many computer vision works demonstrating high levels of precision, availability of data is still a major issue. The level of quality of solutions for specific applications is very reliant on the quantity of data available from that domain. For example, most object detection AI solutions address office/home scenarios, where data is abundant. When considering healthcare applications, data is less available, and these methods are less reliable.

The ability to learn during operation would be valuable for robots. Such learning can be achieved by two means, a human instructing the robot (imitation learning, programming by demonstration) or the robot practicing by itself (reinforcement learning). Imitation learning of motions has become feasible in industrial applications such as packaging where it can significantly decrease the cost of robot programming by empowering end-users to program the robot to new applications. The technology would be applicable for simple manipulation applications such as arranging instruments, medicine, or other objects, although such applications have not yet been demonstrated to our knowledge.

Having robots learn skills by themselves is theoretically a powerful tool. However, in practice, such learning is considered unsafe as it is impossible to avoid collisions with the environment and ensure that humans and/or the robot are not harmed. Thus, robots acquiring new capabilities through learning while operating is currently not feasible. It is common practice to have robots train in simulated environments instead. The main problem when training in simulation is that skills learned there do not always transfer to the real world. This is known as the 'Sim to Real' problem and is a central issue in robotic learning at the moment.

Another limitation that learning algorithms have is that they require data to learn from and in many scenarios, health and welfare included, data is limited or non-existing. If, on the other hand, such data is available, how can we ensure that it is anonymized? These issues limit the applicability of applying learning algorithms in health and welfare, although advances are being seen continuously since the issue of privacy preserving AI has become a popular research topic.

6.1.7 Safety and reliability of robotic systems

Safety of robotic systems can be considered from multiple viewpoints. Firstly, the technological solutions that allow a robot to operate safely close to a human can be studied. Such technologies include sensors that detect humans, for example. Moreover, the process of engineering safe robots can be considered, often related to adhering to standards that pose requirements for engineering practices. Finally, the legal perspective looks at questions of regulation and legal responsibility.

Safety of robotic systems is usually ensured by adhering to relevant standards. At present, the safety requirements for personal care robots in non-medical applications (robots not considered medical devices) are covered by the ISO 13482:2014 standard. The standard covers practices that aim to ensure the physical safety of humans which are colocated in a care robot's operating environment. The standard covers a large variety of robot types and has been applied to floor cleaning robots and small-sized social robots, among others.

Open-source software frameworks are widely used in robotics research and development. While this has significantly increased the pace of developments, the existing frameworks are not ideally suited for safety critical applications. This may limit their applicability in end-user products. This is especially relevant to cases where the size and weight of a robot would be sufficient to physically harm a human.

6.2 Vision for 5-10 years

Next, we will present our visions of which robot applications we expect to be technically feasible and implementable in the near future.

6.2.1 Personal physical, cognitive and social assistance

Robots that provide physical support for increased autonomy of older adults (for walking, eating, household work) tend to have high acceptance among potential users. However, commercial applications are still rare.

The robotic embodiment of an assistant for care is often visualized as a mobile robot with manipulation capabilities. Care-O-bot is the product vision of a mobile robot assistant to actively support humans in domestic environments. Personal physical assistance robots provide the ‘robot servant’ service, but these tools are mainly developed in research laboratories.

Parcel delivery by autonomous systems is available for single floor indoor environments and is being tested for both multi-floor buildings and outdoor use (e.g., Amazon Scout, REV-1).

Support to impaired cognitive capabilities is offered through reminders to take one’s medication or support with exercises (Görer et al., 2013) via robotic systems that have an approachable appearance such as the well-known robots NAO and Pepper developed by SoftBank Robotics, and the robotic seal PARO.

For social assistance, tele-presence robots offer an easy access to family or medical professionals, which helps with loneliness and social isolation (Kristoffersson et al., 2013).

Five years

Robotic mobility aids such as intelligent walking aids that can navigate or help avoid collisions will be available for institutional environments. Critical issues that may inhibit adoption include price, physical safety and reliability.

Single purpose domestic help robots (robotic machines) for purposes such as cleaning and personal hygiene will be available. Critical issues are the same as above.

Parcels will be delivered by autonomous systems, embodied both as ground robots and unmanned drones.

Robots will autonomously have short-term interactions in specific domains such as a health interview, using spoken language and following human social communication norms. Critical issues include technology (modeling social interaction, adaptation to social context), usability, regulation (for regulated activities such as health interview) and acceptance.

Digital-physical assistant robots will support communication between humans and provide information services (search online information, reminders), similar to current digital assistants (e.g., Siri). Compared to pure digital assistants, robots will provide additional sensor/perception capabilities but few if any physical capabilities. Critical issues are similar to the technological issues above, usability, and price.

Ten years

Mobility aids will become available for more complex environments, including outdoors and homes. Critical issues include communication network, long-term mapping technology, reliability and security (including resilience to vandalism and crime).

Robots will perform autonomously repeated interactions such as prescribed therapy in controlled environments. Critical issues are as above plus technological ability to form long-term relationships.

Open dialogue will be available in limited domains for social/cognitive assistants.

General purpose physical support robots (e.g., robotic housekeepers) will not be seen in next 10 years due to their excessive price and immaturity of technology. Only application specific solutions will be available.

6.2.2 Rehabilitation and physical support

Systems that offer support for people with impairments have been on the market since decades (such as walking support), and recent developments are increasing their capabilities with technology. Clinical reality is still currently constrained to assistive robots (stationary devices). These robots aim to replace or support the physical training effort of a therapist dealing with patients. Essentially, the robot carries out the actual physical interaction with the patient. Exoskeletons (non-stationary devices) are still far from mass clinical use primarily due to the cumbersome design and interface impeding the available range of motion and thus limited therapeutic/supportive effect. Either way, robot-mediated therapies have shown some clinical effect and have led to a wider audience having access to much-needed, targeted rehabilitation.

However, the exact effectiveness of robotic rehabilitation remains inconclusive (Cajigas et al., 2017). Some of the reasons behind the mixed success are believed to be the systematic failure to ensure active participation of the patients and a naïve approach to the design of the applied technologies. Lack of active interface capable of reacting and adapting to the needs of the patient and bulky, often stationary, design seem to prevent patients from being actively engaged. This is particularly concerning since the patient exposure to the therapy is limited and the follow up or home-based therapies are far from being satisfactory.

Five years

Robot assistance is going to become more engaging and require users to have more active participation in the rehabilitation process. This is likely to be done by advancing the human-robot interfaces to include more intimate control (derived from user intentions) allowing for establishment of currently missing sensory feedback (electro-tactile, vibro, pressure) that will lead to true sensory-motor integration which is vital for successful rehabilitation. Moreover, intimate control interfacing will allow for more tailored prescription and design of rehabilitation therapies and closer monitoring of rehabilitation progress.

Ten years

With more established presence and streamlined application of assistive robots, and likely advancement of the actuation, power storage and sensing technologies, the stage will likely be set for more prominent deployment of exoskeletons. They will then feature a more streamlined design and offer more versatile control. The assistance will be delivered 'as needed' and the primary type of operation will be volitional control allowing the truly increased mobility of users. Similar to stationary devices, the development of a high throughput human-machine interface will play a significant part in advancing the usability and the acceptance of the exoskeletons among patients and rehabilitation professionals.

6.2.3 Supporting workforce in hospitals and care facilities

Robots have already supported clinical workforce in well-defined tasks especially in hospital logistics (delivering supplies, waste, food, laundry) and administering medication (Bloss et al., 2011). The most well-known system, TUG, automates the delivery of goods for pharmacies, central supply, kitchens or laundry (see Chapter 3.3.3). Advances are being made toward robotic devices that assist in lifting patients or older adults in a semi-automated way. Robear[31] is a robotic system capable of lifting a person from a bed, developed by the Japanese research institute RIKEN. The system is not commercially available.

Exoskeletons are currently introduced to employees in industrial work and in some other services such as gardening.

[31] https://www.riken.jp/en/news_pubs/research_news/pr/2015/20150223_2/

Five years

Semi-autonomous mobility aids such as mobile hospital beds will become available for institutional environments, and logistic robot systems are mature enough to be taken into use in facilities of assisted living in addition to hospitals if the space is accessible (as is the case with wheelchairs). Robots will be employed for disinfection and dangerous activities in highly infectious disease care (e.g., Ebola, coronavirus). Critical issues for hospital logistics are cost, infrastructure (especially communication network availability), worker resistance, and product and support availability (close support desired). Concrete measures and demonstration tools of system performance (e.g., safety, reliability) and cost effectiveness will be needed to communicate the benefits and limitations of the technology.

Telepresence (possibly robotic) and remote health will be used in settings including tele-psychiatry, teledermatology and tele-wellness promotion. Critical issues for telepresence and remote health are communication network quality, mobility of robots (for home settings), privacy and usability.

Ten years

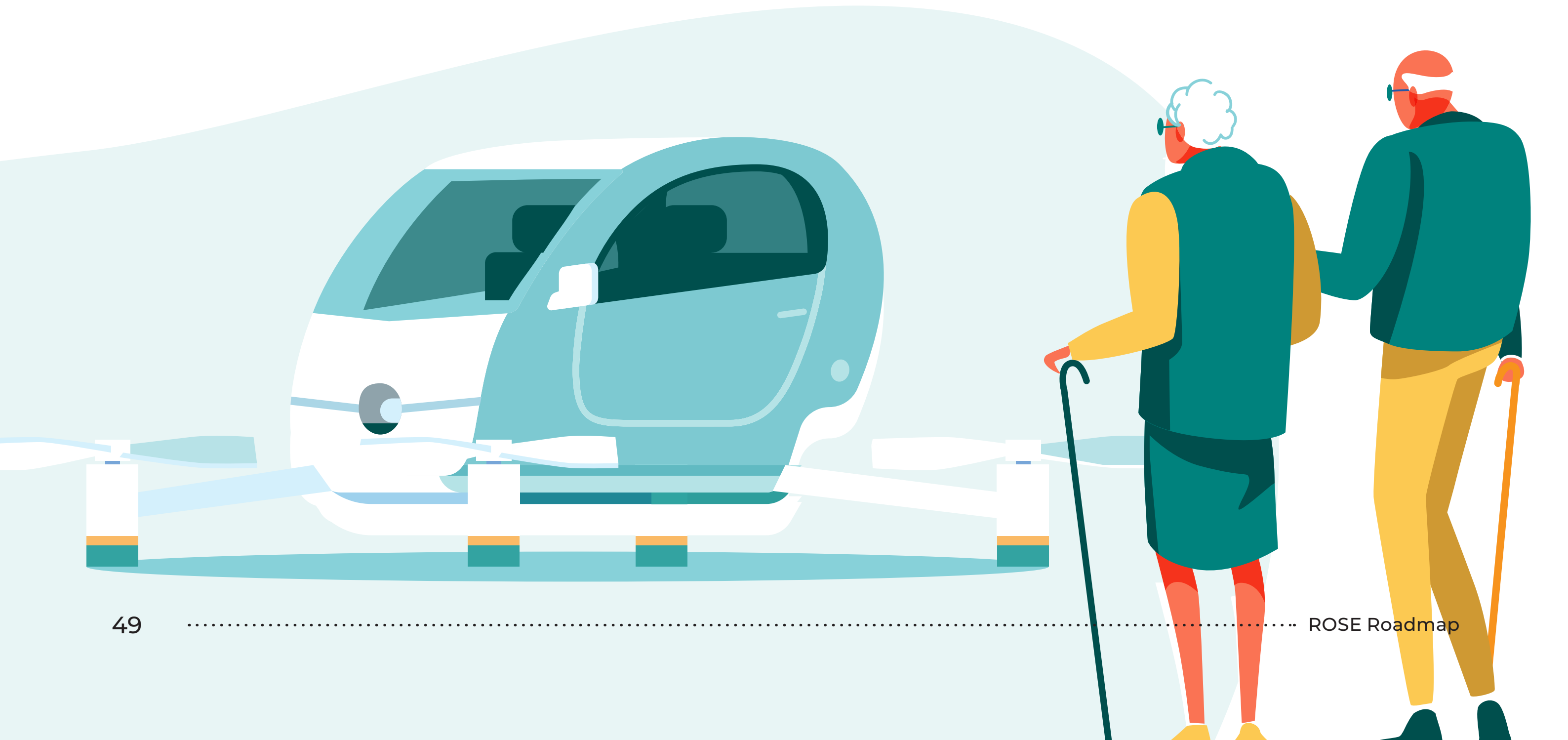
Robots and exoskeletons will support workforce in patient transfer (bed to chair) and patient mobility. Critical issues are similar to the ones above (5 years). As autonomy increases, integration to workflows becomes crucial.

Telepresence robots will acquire semi-autonomous functions, allowing users to use higher-level commands such as navigation goals. Critical issues are the same as above.

6.3 Conclusions

Robots can potentially be used to support a wide variety of tasks in care and independent living. In the short term, promising new applications are likely to be based on either adding autonomous/robotic functions to existing non-robotic devices, or adopting existing robot hardware such as industrial manipulators or mobile logistics robots to new applications in care. In the near future, robots are likely to benefit institutional settings, where robot operations will be more reliable compared to less structured home environments.

In the medium term, robots providing personal assistance, for example in the form of robotic mobility aids and robotic personal hygiene aids, have the potential to mature sufficiently to provide tangible benefits for older adults living in their own homes. To facilitate the short-term benefits in Finland, adaptation of existing technologies as outlined above should be encouraged and related research and development should be supported. Intermediate and long-term benefits will require continuing investments in Finnish robotics research to provide technological readiness and expertise to build new world-class products.



7 RESPONSIBLE ROADS TO THE FUTURE

Contributors: all (see the Appendix)

7.1 Robotization from a broader perspective

The research carried out in the ROSE project has highlighted the potential of robots in healthcare and care services for older adults in many aspects. The main challenges to be overcome in realizing this potential are related to the (im)maturity of technology with regards to the requirements of care settings as well as the (im) maturity of the care robotics innovation ecosystem that would engage all stakeholders including the older adults themselves to co-create, develop, adopt, use and adapt to robot applications in care services.

Care services that fully utilize robots, in addition to other technology and digitalization, are expected to lead to better ergonomics for care workers, increased quality of services (including more accurate and safe medicine dispensing), more autonomy to older adults and patients, and increased attractiveness of care work for new employees. They are also expected to reduce the increasing care service costs. However, these expectations must be studied and monitored from a long-term perspective: short-term pilots of robots even in genuine care settings are not sufficient to foresee the impacts and effectiveness in the long term. Therefore, attention and support should be directed to continuous impact assessment. Research should also be carried out during the implementation of the robots. The developing innovation ecosystem and the renewal of care services need various forms of support, for instance to strengthen the collaboration between technology developers and care organizations, and to educate and train both current and future employees (students) to express their needs and requirements for robot developers. Their knowledge and skills of using robots in practice should also be increased.

However, technological development does not take place in a vacuum; it exists in relation to society's values, structures, institutions, objectives and the capacity of different actors to take advantage of technological opportunities. Therefore, the impacts and effectiveness of technological developments and the possibilities for steering the developments must be assessed at a societal level. While technology may have an innate tendency to make progress by solving previous technological problems, it is obvious that different economic, legal, political etc. arrangements lead to suboptimal use of technology. And in reverse, available technological means might be less than optimal for the culturally and institutionally defined desirable ends, such as the general well-being of humans.

This premise leads us to argue that while it may be tempting to seek technological solutions for problems in care of older people in advanced and ageing societies like Finland, their limits should be acknowledged. The legal-institutional dimension cannot simply be replaced with technological solutions. The same applies to the economic, political and ecological dimensions. The leap from a technology being useful in principle to being beneficial in practice is a major one. All the other dimensions may require so many changes that the time may not be ripe for its use.

It is difficult to estimate to what extent robotization will create jobs. In the past, technological advances have typically created jobs. However, economists such as Daron Acemoglu (MIT) and Pascual Restrepo's (Boston University) have concluded that there is little evidence to suggest that new jobs will be created. A responsible stance seems to be to take seriously the fact that the future of work may be very different from the past and present of work, also in the welfare service sector.

Based on the empirical evidence from the Quality of Work Life Survey 2018 in Finland (Krutova et al., 2021c), the replacement effect of robots and the threat of technological unemployment are real but multidimensional phenomena, depending on both individuals' abilities and resources to adapt to changes at work and, above all, employers' and workplaces' ability and willingness to manage change in a socially responsible way. However, the results of Krutova et al. (2021c) clearly indicate that robotic and non-robotic organizations and professions are polarizing in their own fields. According to them, an employee's flexibility is an important mediator that buffers the structural tensions between job insecurity experienced by individuals, job participation, and career satisfaction (op.cit). Regarding the conflicts between managers and employees, the workplaces where employees report good working environments also see emergence of innovation. All of this points to the important fact that changes in working life can be technology-driven but ultimately it is the people who are responsible for implementation and design of the technology and its use.

Other dimensions of large-scale changes include the role of the environment, including climate change. Some views on this subject are relatively optimistic (see e.g., European Parliament, 2017, §47-48[32]), whereas others are quite apprehensive, including the consensus of climate scientists (see e.g., IPCC, 2014). Ecological aspects should be taken into account when developing technology responsibly. In the responsible planning of the future, even within a 5-10-year frame, the societal upheavals created by climate change should be considered.

In the following, we present policy recommendations for use of robots in care services for older adults so that the potential of care robotics could be realized in a responsible way. The recommendations concern care organizations and services, care workers and older adults, education, the innovation ecosystem, the changing working life, economic, social and ecological sustainability, and ethics.

7.2 Policy recommendations

7.2.1 Robotics research and development

Recommendation 1. In the near future, benefits of robotics will be mostly available for hospitals and care homes, but robots should be better integrated into the services and systems; realizing intermediate and long-term potential of personal assistive robots requires continuous investments in Finnish robotics competence.

Robotics technology and robots provide both short-term and long-term benefits for care work and organizations. The potential of robotics is currently being realized by integrating robotics into existing devices and adopting industrial robots, such as logistic robots or manipulators, in service use. Many applications can be used to assist care workers in their heavy and routine tasks but the maturity of technology for care settings and purposes still needs to be increased. Moreover, **robots need to be better integrated into service environments and systems so that the robot is part of the information-service system of the organization. This requires support for the integration work with standards and open interfaces.** Organizations need support for the integration as well: for instance, assisted living facilities generally lack sufficient network connectivity required for mobile robots.

Large-scale, structured care environments such as hospitals are the first adopters of robots in care support tasks (e.g., transportation tasks, laboratory tasks) but the capability of assisted living facilities to utilize robots should be studied as well: as new infrastructure is built, is there a possibility to integrate robotics into assisted living in a new way, to assist (secondary tasks) in care work? Issues to be studied would include robotic requirements for space, connectivity, integration into electric door and elevator systems, and expected impacts and cost-effectiveness.

In the long term, research that improves robots' capability to safely and easily interact and collaborate with people would greatly increase the variety of applications for care. It would also enable things such as personal assistive multi-purpose robots for ageing people. At present, there are some useful single-function robotic devices for home use, such as cleaning robots and medicine dispensing robots. Conversational AI at home (in Finnish) as well as telepresence robots may be the next step to enable new care services provided at home. Research and development are needed for easy or natural human-robot interaction, manipulation, long-term functioning and autonomy, machine learning and the robot's capability to function in such unstructured environments as care homes and private homes.

While robot technologies are universal, **their adoption into care requires adapting them for national and local contexts,** to allow operation in local language, for example. Consequently, realizing the intermediate and long-term potential of personal assistive robots requires continuous investments in Finnish robotics

[32] European Parliament resolution of 16 February 2017 with recommendations to the Commission on Civil Law Rules on Robotics (2015/2103(INL)): https://www.europarl.europa.eu/doceo/document/TA-8-2017-0051_EN.html

competence. **Research, experimenting and piloting, implementation research as well as sharing of best practices are needed to support the new organization of care tasks and services based on robots.** The development should be based on a user-driven approach and users' real needs and requirements.

7.2.2 Education and training of care professionals

Recommendation 2. Technology competence needs to be fully integrated into the education of care professionals. Competence of care robots includes knowledge from technical aspects and practical use of robots to understanding social and ethical dimensions of robotization in care.

Technological competences in care work must be strengthened through both education and training. Education of care professionals should be better directed at facing future needs where technology plays a bigger role in all kinds of organizations offering care services. Care workers have the right to learn about and get used to new technological devices that affect their everyday work. **Technology including care robotics should be taught as basic knowledge in social and health care education, fully integrated into all study levels.**

The technology competence in care should cover issues from 'hard' technical competences expertise and practical use of robots to work life changes brought about by robot use. These issues include, for instance, abilities to process and analyze data, knowledge about data and cyber security, understanding about social dimensions of robot technology, operational logic and principles of robots as well as usability, skills in design of user interfaces and robotic devices, and knowledge about ethical issues and risks related to robotics.

At work, care professionals need sufficient training in care robots taken into use, and a genuine opportunity to participate in the training in terms of time and work arrangements. The participatory approach in adopting robots in an organization contributes to robot acceptance and the entire organization's capability to change (see Recommendation 5).

7.2.3 Ecosystem thinking and the innovation ecosystem

Recommendation 3. Promoting wide ecosystem thinking and a co-creative piloting and implementation culture facilitates the co-evolution of technology and services, and helps the emerging care robotics innovation ecosystem to grow and thrive.

Wider and deeper understanding of the societal and systemic levels related to robot use is crucial to facilitate co-evolution of technological and service innovations. **This requires ecosystem thinking to be strengthened among all actors and in society at large.** Introducing robots into the care service system means constant negotiations with markets, policies, science, infrastructures, user preferences and thinking models, and the ecosystem thinking is about understanding these negotiations as constantly evolving collaboration among the actors.

The care robotics innovation ecosystem is in its early phases and for it to grow and thrive, a wide variety of stakeholders need to be involved in the ecosystem. In particular, **the user focus in the innovation ecosystem needs to be increased.** Users are diverse, and vulnerable users such as older adults tend to be often forgotten or by-passed in development and design. Purposeful management of the ecosystem is needed to involve users in a systemic way and with sufficient resources. The ecosystem also evolves on its own as various 'forces' accelerate or hinder the use of robots and actors' mutual collaboration.

Service actors responsible for acquiring robots into welfare services (such as municipalities and hospital districts) should play a stronger role by, for example, considering their services from the perspective of opportunities provided by robots and developing their procurement practices and competences. To facilitate this, a better knowledge base needs to be built by streamlining pilot projects, examining impacts of robot use, and sharing experiences and knowledge systematically within the ecosystem.

Research and development actors (such as decision makers, development organizations, research institutes and robot-related firms) should be in closer contact with service actors acquiring robots, and vice versa. By supporting the above-mentioned actions and practices, innovation policy should play an increasingly multi-faceted role to unleash the full potential of care robotics.

Integration of robotics into welfare services should be approached as a 'co-creative piloting and implementation culture' within the wider ecosystem. This type of cross-cutting culture concerns the micro, meso and macro levels and pays close attention to what takes place and emerges during the pilots and, in particular, implementation. It is therefore necessary to investigate the dynamics and coverage of the co-creation (involvement of the users, in particular). Managing such a culture requires valuing direct interaction between diverse people, but also sensitivity towards professional identities, managerial practices, 'states of mind', feelings, responsibilities, and future horizons. Co-creative culture should essentially include participatory methods. This would also result in easier access for technology developers to co-create and pilot with other stakeholders. It would also increase the skills and capability of care professionals and organizations to participate in and arrange co-creation and piloting all the way to implementation. Continuous and early impact assessment is an essential element in the innovation ecosystem development (see Recommendation 4).

From a future-oriented perspective, ecosystem thinking should be developed with the help of educational policies and contents. **Multi-disciplinary programs that combine technical, social and welfare-related issues should be built** (see also Recommendation 2). Cross-educating social and engineering science students in universities also supports this. There's a need to educate a new generation of experts on sustainable development and socio-technical transition.

7.2.4 Impact assessment and evaluation

Recommendation 4. Assessing the impacts and effectiveness of robot use and sharing knowledge about assessment and evaluation results is vital.

Using, piloting and implementing robots is associated with multiple types of impacts that may be positive, negative or neutral. They may be related to quality of services, various impacts on care personnel and costs (including the technology), inter alia. In the longer run, it is vital to examine if the aims of robot use have been reached; that is, if there is true effectiveness.

Many small-scale pilots of robots have been conducted, but wide-spread adoption requires understanding of both short-term and long-term impacts as well as effectiveness. This calls for collecting and compiling information from the pilots as well as coordination among them, and implementation research. **The research focus should shift from small, short-term and scattered pilots to implementation research, which provides a longer-term view of robot integration challenges and opportunities than pilots.** Longer-term pilots and implementation will require greater public investment, but such investment should be made for cases where there are justified expectations of major positive impacts from the smaller pilots.

One should also be aware of the limitations of smaller pilots. Also known as the Collingridge dilemma (Collingridge, 1985; Genus & Stirling, 2018), controlling the development of technology is easier in early stages when its full impacts cannot yet be known. The impacts of a certain technology will only show themselves fully as said technology takes hold in the institutional settings, i.e., when the relevant technology is in operation, particularly in the long run. Smaller pilots can still offer relevant information on understanding and anticipating the acceptability and needs of future technology. Moreover, careful impact assessment of pilots is likely to unveil invisible or seemingly irrelevant processes and stakeholders that should be considered when making corrective actions and when negative impacts are observed. Implementation research, again, provides a longer-term view of robot integration challenges than pilots. As a solution to the dilemma of controlling new technology we emphasize **thorough impact assessment during every step of piloting and implementation, ex-post evaluation of pilots, and sharing of knowledge about the results of all these initiatives.**

Ex-ante scenarios can also be built to foresee opportunities provided by robot technologies before any piloting and implementation decisions. Depending on the stage in question, various stakeholders (such as technology and service developers, researchers, those involved in the practical piloting or implementation, managers and policy makers) should participate in impact assessments and evaluations. The accumulating assessment and evaluation data and knowledge should be actively shared and disseminated in, for example, different online platforms such as Innokylä[33].

7.2.5 Acceptance of robots at work

Recommendation 5. Acceptance of robots at work can be seen widely as an organization's ability to change; both can be supported by improving the working conditions for the employees.

The adoption and effective use of robots in an organization depend to a large extent on the acceptance of the technology (among employees) and the readiness of the organization to change. Technology acceptance is typically addressed as a question of the features of the technology (e.g., usefulness, easiness of use) as well as characteristics of the potential users (e.g., level of education). However, the organizational and workplace level factors like working conditions, employee empowerment, and employees' perception on whether they have a share from the productivity increase earned with robots, play an important role. Therefore, **acceptance can be increased, and organizational change facilitated by supporting and training employees and making them the agents and active contributors of change.** Sufficient training is required to both ensure the successful adoption of a robot application and to build a robot-positive mindset in the organization in the longer term.

[33] https://innokyla.fi/fi. Innokylä ("Innovillage") is a Finnish open innovation online platform and community for health and welfare sector.

In general, employees have a need for well-being, motivation, autonomy or sense of meaningfulness at work. Technological change as such may not improve these or create interesting work tasks. These objectives can be achieved better by developing the empowerment, trust and support of employees as well as equal share of benefits gained from technology. An organization's productivity growth is more probable when use of robots is combined with well-trained, skilled and motivated staff.

Acceptance of robots at work can be increased also by cross-organizational and even cross-sectoral activities such as sharing best practices and successful use stories and experiences of robots. These activities can be a part of the sharing and dissemination of assessment and evaluation data and knowledge (see Recommendation 4).

7.2.6 Change of working life

Recommendation 6. The change security of the working age population must be supported to decrease the risks of deepening inequalities within working life.

In the era of digital transformation, the goal is a dynamic, innovative, knowledge-driven economy; but the more dynamic the economy, **the more robust the safety net should be in order to cope with the steady disruptions and gaps in employment, wealth and power among citizens that results.**

Although mass unemployment is not expected to become the primary problem in the care sector in the short term – rather the opposite: there is an increasing shortage of care workers – actions should still be taken to support employees in the changing and digitalizing working life. Not everyone is a winner in the technological change or protected from the erosion of work and labor market positions. There is a risk that rampant technological change will deepen the already prevailing divisions and inequalities between for example, educated and uneducated workers within working life. In order to speed up technological modernization and to smooth out or avoid unexpected, undesired outcomes of robotization, there is a need to develop the change security for all groups of working age population.

One step is to invest more in technology education, to support the employees', organizations' and the service system's ability to embrace technology (see also Recommendation 2). As the care sector employs immigrant workers as well – likely an increasing number in the coming year – their training in technological skills should be taken care of. A mindset of lifelong learning is needed in all employment sectors.

7.2.7 Sustainable implementation

Recommendation 7. The implementation of robots in public welfare services should include sustainability-based assessment, covering economic, social and ecological issues.

Robots are expected to play a much more significant role in health and social services within the next 10-20 years than they currently do. However, this includes specific challenges stemming not only from the specific characteristics of the health and social services sector, but also from the social and global changes. These include changes in labor supply and educational needs in the welfare sector, technological developments and public finance developments, as well as ecological issues such as the climate change, material use in technology production, consumption and recycling.

To ensure that the implementation of robots in public health and social services meets these challenges in an economically, ecologically and socially sustainable manner, a systematic sustainability-based assessment is proposed.

The sustainable robotics assessment model could be built on existing assessment methods, for instance the national Digi-HTA assessment criteria[34], which measures the suitability of technology solutions in the health

[34] https://www.oulu.fi/cht/digihealthhub/digi-hta
https://thl.fi/fi/tutkimus-ja-kehittaminen/tutkimukset-ja-hankkeet/hyvinvoinnin-tekoaly-ja-robotiikka-ohjelma-hyteairo-/digi-hta (in Finnish)

and social services sector. We propose that the evaluation criteria, from a sustainability perspective, should include three main categories: economic, social and ecological sustainability.

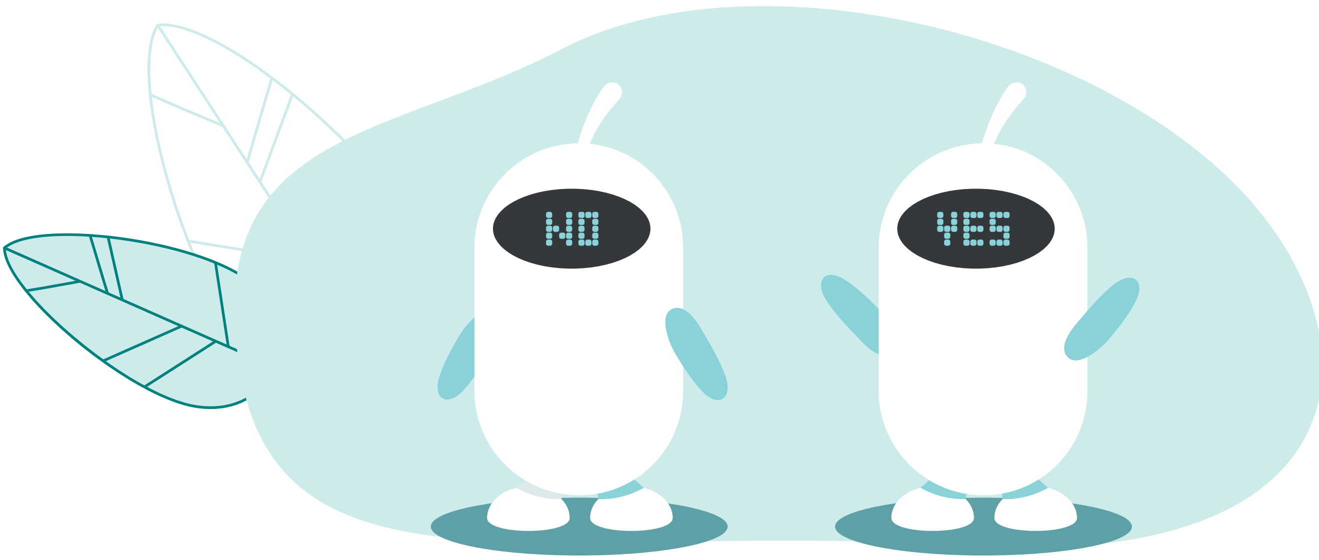
Economic sustainability review complements the cost-effectiveness assessment by also assessing the promise that the technology holds with regards to state of development and scalability. The social sustainability perspective will assess how well-suited the robotic technology is for working as part of everyday practices and complements the resources in the health and social services by still maintaining the committed ethical standards and norms in the field. In terms of ecological sustainability, the impacts of robotization on climate change (e.g., the relevance of the robot in reducing travel needs) and the use of natural resources (such as the robot's energy needs and sources) will be assessed compared to current systems or practices.

7.2.8 Ethics

Recommendation 8. Robots in care should support human dignity and autonomy and not reduce human contact. Ethical impacts of using robots in care organizations must be monitored both in the short and long term.

Ethical analyses of robots in care have shown promising results towards their impact on autonomy, loneliness and ensuring dignified care and aging. Despite these encouraging results, robots can also pose a threat to these very same things as their use can result in loss of autonomy, objectification of patients and loneliness through reduced human contact. With social robots there are also concerns of whether the robot is framed or understood as a carer or as a tool. **Care organizations need to pay attention to both short-term and long-term impacts of adopting robots in care and arranging services based on robots (and other technologies).** Ethical considerations should be part of the impact assessment and implementation research to understand the longer-term aspects of the integration of robots in care (see also Recommendation 4).

There have been clear signs of a hype phenomenon with regard to care robots in the media and even among scientists. There is a tendency to report on individual robot experiments that cannot be realistically implemented in care settings in the near or even farther future. From a practical standpoint, the state-of-the-art robotics allows simple or single-purpose devices with minimum or without direct physical contact to older people or care workers. This makes it difficult to evaluate the ethical impacts of robots in care, particularly those of socially interactive robots, companion robots and robots that would be used in close physical contact with the older adult or patient (such as an autonomous lifting robot). Robot ethics can provide guidelines in how robots should be used but **human care must be organized ethically and sustainably first and foremost, whether with or without robots.**



8 REFLECTION: WHEN SOCIAL SCIENCES MEET ENGINEERING

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This roadmap has been prepared as one of the results of the research project Robots and the Future of Welfare Services (ROSE), funded by the Strategic Research Council (SRC). The ROSE consortium was one of the firsts to be accepted in the new program of strategic research projects of the Academy of Finland. One of the main criteria was that the consortium needed to be multi-disciplinary: the issue at stake needed to be approached from different angles and by using several scientific frameworks as a tool to increase knowledge. Multidisciplinary approach was an important objective of the ROSE consortium from the beginning. To include several relevant disciplines and expertise was a way to tackle the complexity of technological developments in society and in the services.

The research projects in the ROSE consortium have investigated robots in welfare services from the perspectives of engineering, human factors, social sciences, organizational research, business and innovation research, and philosophy, ethics and history of technology. As such, the ROSE project has also been an academic journey to understand the relationship of sciences (engineering) and humanities (social sciences). In the following, we highlight some learnings from this journey.

8.1 Need for sound socio-technical solutions

From the point of social constructivism, technology is driven by social, political and economic structures of the society (e.g., Šabanović & Chang, 2016). From this perspective it is clear that all advancements and developments in the production or social systems cannot be explained by technological change alone, as much as this is implied by technological determinism. In Finland, for example, the function of the welfare state and its institutions are shaping the course of technological development. In addition, individual and social determinants are quite decisive when people adopt technology as a part of their lives.

Both the statistical survey studies and the case studies we carried out among professionals and end-users in private dwellings, care homes and community apartments proved how the success or failure in introducing robots is linked to the compatibility of users' skills and preferences, the operating environment and the quality of coaching provided.

Learning 1.
Beyond technological determinism

The empirical findings of our studies verify that even the major obstacles in care robot implementation often originate from the dissonance between the technology and the human user. In a world of touch screens, it is a real problem when an older user's fingertips are so dry that they cannot be read by the screen of the robot. Furthermore, operation environments have attributes that do not play well with robot technology. Internet connections do not reach all areas where the robot is supposed to work (such as elevators) and there are floor materials, cramped spaces and thresholds that restrict the mobility of robots. Hence, the barriers to technological development are not only a question of the technology itself, but also factors arising from the social, human and functional environment in which technology operates. This leads to second learning.

Learning 2.

Socio-technical solutions are required to support the existing norms

It is important to consider that even the most autonomous service robots cannot operate quite irrespectively of their systemic conditions. The proper execution of robotic tasks presupposes that relevant technical capabilities are on hand but also that their necessary institutional and organizational aspects are identified and managed. This is especially important when considering robotic implementations in the context of public health care. The quality of care services depends not only on policy level decisions but also on factors like up-to-date professional training and preparedness of the end-users. In a welfare context, robots are stepping into human-centered service work. It should be acknowledged that it is the skills that develop through care practices which ensure that the care values are met in everyday welfare services (van Wynsberghe, 2015, p. 33-36). It is therefore always questionable to employ robots in a care situation without a care professional involved.

The factors described above suggest that technological development is heavily guided by policies, laws and institutions as well as more informal norms. In guiding the technological development and robotization, attention should be paid above all to the context, environment and conditions in which the technology is intended to be developed and exploited.

8.2 Organizations and macro-economic policies

The acceptability of new technologies depends mostly on the experiences and individual characteristics of individuals as well as the technology itself, but the characteristics of the work community and organizations are important determinants as well (e.g., Krutova et al., 2021a; Krutova et al., 2021b; Turja et al., 2019). These findings lead us to the third and fourth learnings.

Learning 3.

Multi-level approach to technological transformation in services

The speed of innovation is important for the competitiveness economy and wealth of the society, but innovation process itself is a highly complex process and difficult to steer and anticipate. Influencing the innovation direction is even harder. Consequently, the robotization should be seen in frames of a wider societal process and ecosystem. The search of service innovation through robotization should be extended beyond the Human Resource Management research to cover the combination of hardware, software, and orgware, where orgware refers to the various components and institutional settings of the innovation system.

However, we will point out once again that managing this process is a demanding task and requires that the interests of the various actors are identified and long-term investments are accepted. National resources for R&D are often limited but the overall openness of economy and institutions of the welfare state offer excellent opportunities to utilize the global results of research and development and to be able to quickly utilize the innovative ideas that emerge internationally.

Learning 4.
Organizational factors to be taken account in robot acceptance

The research findings based on organization level research suggest that technological development is dependent on the workplace. The existing research suggests that the competitive advantage provided by technological development depends to a large extent on the speed and coordination of the technology's implementation, and on how well the technological applications are considered. Our results of empirical research indicate further that the characteristics of workplaces, such as the employees' participation and involvement in the development of the organization, play a significant part in both the acceptance and the implementation and outcomes of the technological transformations in the workplace.

All these things considered, we conclude that the Technology Acceptance Model (TAM) provides a good framework for analyzing the acceptance of technological reforms, but it should be extended to include the relevant organizational and macro-economic factors in the margins. Based on the results of our empirical studies, we show the importance of individual, organizational, and wider contextual factors in robot acceptance.

Learning 5.
Improving and utilizing of technology databases

Service robots and the possibilities of utilizing them are driven not only by end users, but also by consumers and their readiness to apply new technologies. This means that future studies should pay more attention not only to technology, but also to broader social frameworks and adequate data. The acquisition of research data should be systematically extended to enable the study of the phenomena of complexes. In order to make this happen, researchers should also be more sensitive to how they describe the qualitative characteristics of technology (robots) in various organizational and social contexts. This would lead to a cumulating knowledge base of robots that could be better utilized in monitoring and evaluating impacts of robots also at a national level.

8.3 Adaptation and transformation in society

First, it is evident that Finland has limited funding for investments in research and development and should therefore be able to identify specific areas of robotics and digital systems where it is at its strongest. Second, to cope effectively with the external and internal disruptions, such as climate change, pandemic or structural deficits of care and technological changes, society has two alternatives: either to change existing practices within the existing social-ecological systems (adaptation) or enact more fundamental changes that can alter the dominant social-ecological relationships and social relations (transformation). Our experience with the ROSE project leads us to the following recommendations.

Learning 6.
Robotization in the perspective of global challenges

Referring to the experience gained from previous research as well as our own case studies and surveys, we strongly recommend that future research examine robotization as a holistic phenomenon: How different domains of adaptive capacity—assets, flexibility, organization, learning, socio-cognitive constructs and agency—are related to adaptive and transformative actions that are needed to address global challenges.

This means a real extension of the scope of robotic studies towards relevant societal factors which will enable and inhibit innovations. As socio-technological and philosophical arguments have underlined for decades, technological innovations are transformed or 'translated' into real facts only in the final context and the use environment. Service robots in general but socially intelligent service robotics in particular will be fascinating test beds not only for novel technical solutions but for new humanistic concepts as well.

Learning 7.

Decision-making in robotization needs further research

The service industries, and the public sector services especially, have a specific role in the restructuring and performance of economies. The technology acceptance and the speed and efficiency of new technologies depend heavily on demand, purchasing power and how well technology meets consumers' wishes. In all these contexts, the decisive factor was who made the technology choices, for whom these choices were made and who covered the cost. Nevertheless, consumer ignorance, lack of producer incentives, complex production interdependencies, and market fragmentation are factors which have been studied insufficiently. These issues are the key question which should be studied more carefully especially in context of Nordic-type, public-private mix of the welfare state.

8.4 Needs for an interdisciplinary and a multilevel approach

Robotic solutions matching the needs of normal living environments are still in their early stages. This is especially true in case of multifunctional robots since households and service work robots of today are single purpose automatons. However, teleoperated robots face major challenges in their attempt to find a place in social contexts and environments as well. Where industrial robots can be designed to operate in highly structured and standardized environments with strict task definitions, service robots need to operate in extremely versatile changing and complex situations. Service work robotization entails many politically, socially, and ethically critical issues that require interdisciplinary and multilevel analysis.

Learning 8.

Interdisciplinary platforms are a long-term asset

Besides interdisciplinary research, ROSE consortium has organized interdisciplinary courses on "robotization and society" and received promising feedback to further develop interdisciplinary measures to address current technological and societal issues with new generations.

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