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Pekkarinen Satu, Tuisku Outi, Hennala Lea, Melkas Helinä

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Satu Pekkarinen*, Outi Tuisku, Lea Hennala, Helinä Melkas

*corresponding author

Satu Pekkarinen
Lappeenranta-Lahti University of Technology LUT
School of Engineering Science, Lahti Campus
Mukkulankatu 19
15210 Lahti
Finland
satu.pekkarinen@lut.fi
+358 40 568 9248

Outi Tuisku
Lappeenranta-Lahti University of Technology LUT
School of Engineering Science, Lahti Campus
Mukkulankatu 19
15210 Lahti
Finland
outi.tuisku@lut.fi
+358 550 325 1881

Lea Hennala
Lappeenranta-Lahti University of Technology LUT
School of Engineering Science, Lahti Campus
Mukkulankatu 19
15210 Lahti
Finland
lea.hennala@lut.fi
+358 40 558 4879

Helinä Melkas
Lappeenranta-Lahti University of Technology LUT
School of Engineering Science, Lahti Campus
Mukkulankatu 19
15210 Lahti
Finland
helina.melkas@lut.fi
+358 40 588 1400

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Abstract

This paper considers the dynamics of the emerging care robotics innovation ecosystem in the Finnish welfare services. Innovation ecosystems have both evolutionary nature as well as aspects of purposeful design, and we study the relevant actors, their roles, the accelerators and the barriers, by conducting a survey among relevant stakeholders in the innovation ecosystem. An online survey was conducted with a range of Finnish stakeholders (N=250): service actors (n=148) and research and development actors (n=102). The responses of the two groups were analysed with a pairwise t-test. The results show that a variety of stakeholders are needed in ecosystem. The role of micro-level actors, such as workmates and professional and private robot users, were considered as important. Service actors should also play a stronger role in the ecosystem. In particular, research and development actors seemed to be open to new stakeholders entering the ecosystem and highlighted the importance of collaboration between actors. The culture of piloting in Finland is accelerating the ecosystem, but attitudinal factors, such as fears and resistance to change are hindering its development. The ecosystem is dynamic, and the dynamics in the ecosystem seem to be largely based on social and cultural issues.

Keywords: Innovation ecosystem, Ecosystem dynamics, Care robots; Service robots; Welfare services; Finland

1 Introduction

Digitalization does not only mean the use of technological tools in service delivery processes, but a fundamental and transformational role of information technologies as resources in service innovation, where technologies are combined with other resources such as skills and knowledge (Barrett, Davidson, Prabhu, & Vargo, 2015). Firms are moving from a traditional manufacturing identity to a service orientation and, along with greater technological advancement, a service orientation is essential for digital transformation (Ng and Vargo, 2018). Robots are expected to have important implications in services; at the micro (i.e. individual customer experience), meso (e.g. the market for a particular service and market prices) and macro level (e.g. societal implications) for all key stakeholders (Wirtz et al., 2018). The introduction of robots into society and the development of robotic innovations have introduced a profound technological transition where the challenge is the simultaneous development of technologies and new service operations. The question is not only about technological development as seen in a 'vacuum' but also about the interactions and entanglement of technical artefacts with organizations, actors, structures and social practices (Geels, 2005; Fraedrich, Beiker, & Lenz, 2015).

The development of care services is strongly affected by digitalization, and more recently, this has included service robotics. There are several triggers for this, such as an ageing population and a sharp rise in the dependency ratio, with its increasing need for a care work-force. Robots in elderly care have an effect not only for the elderly person him/herself, but also for the whole value network around them (Čaić, Odekerken-Schroder, & Mahr, 2018).

Thus, the development of robots should be studied as an emerging innovation ecosystem, consisting of various actors and representing different interests and fields of expertise. Innovation often results from the interaction of different actor-networks, comprising users, producers and related organizations (e.g. Melkas and Harmaakorpi, 2012). For instance, developing successful welfare products requires a combination of knowledge from both the welfare sector and production. The actors in a process may have little knowledge in common, but their collaboration is required to bring together a number of competences and cultures (Pekkarinen and Harmaakorpi, 2006). In most cases, innovativeness depends on a network's ability to interact rather than on the progress of an individual actor in a particular scientific field (Tura and Harmaakorpi, 2005; Melkas and Harmaakorpi, 2012).

Finland is taking the initial steps towards building a care robot innovation ecosystem in welfare services. Currently, the innovation ecosystem is immature and essential stakeholders are missing or not systematically involved. However, there appear to be good opportunities for building a functioning innovation ecosystem around care robotics because of long traditions in both the welfare services and technological expertise in the country (Hennala et al., 2017). Care robots in Finland have been piloted in various use environments, but, when considering their wider use and acceptability, it is suggested that robots need to be better integrated with other care technologies and also with the existing processes and information systems (Hennala et al., 2017). Earlier studies on other types of welfare technology suggest that procurement issues, problems in integration and a lack of a holistic perspective are all inhibiting factors (Melkas, 2013).

In this study, we focus on the dynamics affecting the emergence of the care robotics innovation ecosystem in welfare services – on the forces that produce movement or change. In this context, these forces are understood as the relevant actors, their roles and the accelerators and barriers affecting the emergence of the ecosystem. This paper focuses on questions relating to the roles and collaboration of the different stakeholders in the field of robotics in welfare services in Finland. Finland can be seen as an innovation network where the identification of stakeholders can be extended to other countries as well. We discuss the present literature on innovation ecosystems, the current state of Finnish welfare services and the state of the Finnish care robotics innovation ecosystem in welfare services. To contribute an empirical dimension to this paper, we introduce the results of a survey conducted in Spring 2017. These provide an understanding of the dynamics of the care robotics innovation ecosystem in welfare services.

Our main research question is: What are the key factors in the dynamics of the emerging care robotics innovation ecosystem in welfare services? We study this question through the following sub-questions: With whom have the different actors collaborated and discussed in the emerging multi-faceted innovation ecosystem? Which necessary actors are missing from the discussion? Which accelerators could boost the emerging care robotics ecosystem in welfare services? What barriers can be identified? We tackle the emergence of the ecosystem as a whole, but we also study possible differences between service actors and research and development (R&D) actors.

Our study contributes to existing ecosystem literature by tackling the less studied field of the birth and emergence of ecosystems (e.g. Dedehayir, Mäkinen, & Ortt, 2018), with a specific focus on the dynamics of an emerging care robotics innovation ecosystem. The contribution to the literature is also about providing an empirical case study on the aspects of purposeful design and evolutionary nature of the innovation ecosystems (see Ritala & Almpanopoulou, 2017).

2 Theoretical Background: Innovation Ecosystems

This paper is based on the concept of the innovation ecosystem (Adner, 2006; Adner and Kapoor, 2010). This concept, 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, Figueiredo Facin, Salerno, & Ikenami, 2018; Shaw & Allen, 2018), and in regional development (Rinkinen and Harmaakorpi, 2018). According to Moore (1993), firms should not just be viewed as part of an industry but as part of an ecosystem where companies cooperate, compete and co-evolve capabilities around innovations. He defines a business ecosystem as ‘a collaboration to create a system of complementary capabilities and companies’ (Moore, 2006, p. 53).

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). De Vasconcelos Gomes et al. (2018) identify a dividing line between the business ecosystem and the innovation ecosystem: business ecosystem relates mainly to value capture and the innovation ecosystem relates mainly to value creation. 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. In this context, 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. The innovation ecosystem thus comprises two distinct and largely separate economies: the knowledge economy, driven by fundamental research, and the commercial economy, driven by the marketplace (Jackson, 2011).

Moore (1993) defines four stages in the development of a business ecosystem: birth, expansion, leadership and self-renewal or death. As in biological ecosystems, each member shares the fate of the whole (Moore, 1993; 2006; Iansiti and Levien, 2004). Due to possible conflicts between the success of an ecosystem and the individual (Nambisan and 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 and Levien, 2004). In this study, this was done when preparing the survey. Ecosystems cross a variety of industries and include several domains (Iansiti and Levien, 2004). Ecosystems may also contain independent niches that can be developed within the ecosystem through specialized new ventures (Moore, 2006; Zahra and Nambisan, 2011). Moore (2006) also discusses the concept of space as a domain for a business opportunity. It reflects a space for a future business activity that does not yet exist or is only in its start-up phase (Rinkinen and Harmaakorpi, 2018).

The ecosystem concept has been perceived as having a self-organising and self-renewing nature. For instance, Peltoniemi and Vuori (2004) state that if the theory of ecosystems as complex, self-organising and self-sustaining systems is adhered to, no government intervention should be needed for them to survive in the global market. However, Oh, Phillips, & Lee (2016) even see innovation ecosystem as a designed entity instead of 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 organiser (Ministry of Social Affairs and Health, 2018). Taken this, it is important to understand which parts of the ecosystem can be engineered and which parts are self-organised or co-evolved (Ritala & Almpanopoulou, 2017).

The innovation ecosystem has also been criticised. For instance, Oh et al. (2016) state that very little is gained by adding ‘eco’ to the national and regional innovation systems. They argue that an innovation ecosystem is not an evolved entity, but has rather been designed for an intentional action. Thus, the analogy to a natural ecosystem is flawed (Oh *et al.*, 2016). They also note that, in the literature, authors use the term ecosystem inconsistently. The problem is that there is no consensus of the term’s definition, scope, boundaries, or theoretical roots (Ritala & Almpanopoulou, 2017). Ritala and Almpanopoulou (2017) have demanded paying attention to both of the parts of the term: ‘eco’ and ‘system, and aiming at greater rigor in innovation ecosystem research, without needing to abandon the concept.

Ritala and Almpanopoulou (2017) suggest that the concept of innovation ecosystem fits especially to market-based initiatives, 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 in 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, the emergence of the innovation ecosystem has been little studied. Dedehayir et al. (2018, p. 18) note that 'while ecosystem genesis has reached very limited attention hitherto, it is a topic that is likely to carry substantial implications not only for practitioners and scholars alike, but also for policy makers whose efforts are directed towards promoting economic welfare within sectors, regions and nations'. For these reasons, this study was conducted.

3 The Context of the Study: Care/Service Robots and Welfare Services in Finland

3.1 Service Robots and Care Robots

Service robots[1] are a concrete example of service digitalization and service provided by technology and humans in collaboration. In this study, we focus on care robotics as a sub-category of service robotics. Care robots are service robots that are utilized in welfare services, and in this way they can be separated from the service robots in different fields, although, their task are quite similar to other service robots (Okamura, Mataric, & Christensen, 2010). The service robots utilised in care services may be monitoring robots (helping to observe health behaviours), assistive robots (offering support for the elderly and their caregivers in daily

[1]Robots can be divided into two categories: industrial robots and service robots (International Federation of Robotics [IFR], 2012). Industrial robots are used in manufacturing processes. Service robots are used by service providers or individual consumers. Service robots are not a homogenous category of technology but exist in many forms, sizes and purposes.

tasks), and socially assistive robots (providing companionship) (Wu, Fassert, & Rigaud, 2012). Another categorization is presented by Cresswell, Cunningham-Burley and Sheikh (2018; Table 1). Table 1 shows both types and uses of robots in care. Their actual integration in care systems varies greatly, and new types are constantly developed (e.g., for personal hygiene).

Table 1.

Uses of health care robotics (adapted from Cresswell, Cunningham-Burley & Sheikh, 2018).

Type of device	Autonomous	Semiauto-nomous	Operational	Health care delivery, patient- and staff-facing	Examples (see also, e.g., Okamura et al., 2010; Truelsen & Andersson, 2019)
Service robots (eg, stock control, cleaning, delivery, sterilization)	✓	✓	✓		Roomba
Surgical robots		✓		✓	Da Vinci
Telepresence robots (eg, screens on wheels)		✓		✓	Double, Giraff
Companion robots	✓			✓	Care-O-bot
Cognitive therapy robots	✓			✓	Paro, JustoCat
Robotic limbs and exoskeletons		✓		✓	Indego
Humanoids	✓		✓	✓	Zora, Pepper

The development of service robotics takes place in the arc of suspense between supply (technology push) and demand (demand pull). Thereby, especially the interdependencies between services on the one hand and technology on the other have to be considered (Ott 2012). Here technological innovation perspective is linked to other innovation perspectives, where e.g. boundaries between manufacturing and services are blurred (Drejer, 2004). One reason for this is that even technological innovation does not always mean the creation of radically new technology, but instead, technological innovation refers also to more compatible solutions, where social and service innovations are needed (see Pekkarinen and Melkas 2017). Very few firms are producing or working with service robots. Leigh and Kraft (2018) investigated the prevalence of robots in the US and found that, out of 856 robot-related firms, only 91 produce or work with service robots. A similar situation is likely to prevail elsewhere around the world.

3.2 Current Status and Trends in Social Welfare and Healthcare Services in Finland

In this study, welfare services mean the social and healthcare services. In Finland, the public sector is responsible for organising these services, and traditionally, these were the responsibility of the municipalities. The Finnish healthcare system provides comprehensive health care for all citizens. The funding for public healthcare services is mainly handled via the Finnish tax system, and charges to service users are low.

There has been a need for a reform due to an increased need of social and healthcare services along with the population ageing, and a debate on the changing role of the public sector and an increase in private- and third-sector care providers. Digitalization has played a major role in the planned reforms. The government has adopted strategies to implement digitalization in government and public services and in ICT related operations in the social, healthcare and local government services. Digital tools enable services to be delivered in a fresh way and service processes to be optimized. The aim of the e-services is to help citizens maintain their well-being and health (Ministry of Social Affairs and Health 2018). However, concerns have arisen regarding citizens' access to digital services and their rights to equal opportunities as well as the changing work tasks of care professionals with their new demands and requirements (Hyppönen and Ilmarinen, 2016).

3.3 Current Status of the Finnish Care Robotics Innovation Ecosystem in Welfare services

Reflecting on the Finnish situation in relation to Moore's (1993) four stages of the development of business ecosystems shows that the robot ecosystem is still largely in its birth stage. Only a few Finnish companies are involved, and they are usually small, so it does not yet seem appropriate to discuss a network in which value is co-created (Peppard and Rylander, 2006; Leviäkangas et al., 2014). Because the innovation ecosystem is immature, essential stakeholders are missing or are involved in many additional activities (Hennala et al., 2017). In contrast, monitoring systems and telecare have been piloted and integrated into care, and these technologies have reached a mature stage. However, there are only a few care robotics (service) providers, and their technologies are relatively immature and their connections to the care ecosystem tenuous. The collaboration of care robotics service providers in the ecosystem has mainly comprised piloting of care robots in different use environments (care facilities and homes of seniors) together with research and development (e.g., Melkas, Hennala, Pekkarinen, Kyrki, 2016; Niemelä, van Aerschot, Tammela, & Aaltonen, 2017). These pilot studies have been fairly loosely connected to the real aims of care. Robots should be integrated into other care technologies, and into the existing processes and information systems in care (Hennala et al., 2017). At the same time, there should be greater emphasis on the anticipated impact of care robots on users.

According to Ruohomäki's (2017) study investigating expectations and prospects for the use of care robots in Finnish elderly care, there is real business potential for care robots in supporting elderly people to live independently at home and in doing tasks where human contact is unnecessary. Certain obstacles need to be overcome before robotics can be properly introduced into the welfare services. At the societal level, there is resistance to adopting the use of robots in welfare services. This resistance is based on concerns such as fear of progress or fears that robots will replace human care (Tuisku, Pekkarinen, Hennala & Melkas, 2019). Despite this resistance, there are still a number of start-up companies working with different types of robotics with the aim of making them more generally available. However, robot producing companies are mostly interested in mature and cost-effective technologies that facilitate economic solutions. These companies have raised several challenges for instance: the obscurity of the payers (partly due to the complexity of Finnish public administration), the lack of procurement skills, the lack of wider-scale impact studies and research data, and the lack of credible skilled national operators who could connect care technologies to the related services and service users (Hennala et al., 2017; Ruohomäki, 2017).

4 Materials and Methods: Survey

An online survey was conducted in February–March 2017 with a range of Finnish stakeholders. Based on the idea of innovation ecosystem comprising both producers and users/consumers, the robot innovation ecosystem was identified as involving, on one hand, the service actors who are responsible of acquiring robots in welfare services (e.g. municipalities and hospital districts) and on the other, the research and development actors (the decision makers, development organizations, research institutes and robot-related firms), whose tasks are related to the development work of robots, from different perspectives

The survey covered following elements: background information, general questions about robotics, robotics issues in welfare services and questions related to care robots. In this paper, we will concentrate on analysing questions concerning the network related to the use of robots in the welfare services. The questions were in Finnish but are translated into English.

4.1 Participants

Altogether 250 persons (71% female, 29% male) answered the survey with a response rate of approximately 25%. The age distribution was as follows: 6% of respondents were 26–35, 16.4% were 36–45, 29.2 % were 46–55, 38.4% were 56–65, and 10% were over 65 years old.

The participants were divided into two response groups: the service actors (n=148) and the research and development (R&D) actors (n=102). The service actors consisted of respondents who had received the survey through Finnish municipalities or hospital districts. They included persons who were working within elderly care services in municipalities and also municipal-level decision-makers. These people can be considered present or potential users of service robots. They have more ‘hands on’ expertise in the welfare services than the R&D actors.

The R&D actors were the national actors and consisted of members of parliament, the ministries, enterprises in the field of robotics, associations and research institutes. In this group, the participants represented a wide range of professions. These respondents represented decision makers, robot entrepreneurship, researchers and so on. They can be considered the producers of technology and knowledge relating to service robots. That is, they had less practical expertise related to the welfare services but they were interested or involved in welfare services through the development of policies and technologies or through conducting research related to the area.

4.2 Data Analysis

Factors that hinder or accelerate the development of the robot ecosystem were investigated by asking two questions: (1) Which of the following factors hinder the introduction of robots into welfare services in Finland? (2) Which of the following factors accelerate the introduction of robots into welfare services in Finland? These were both multiple-choice questions where the participants could select as many of the options as they wished. Each of the options was treated as a single variable in the analysis. The questions were coded so that if a participant selected an option, the response was marked as 1, and if the participant did not select an option, it was marked as 0. A pairwise t-test was then used to compare the responses of the two groups.

Collaboration within the emerging ecosystem was investigated through four questions: (1) With whom (in your profession) you have discussed the use of robots in welfare services? (2) With whom you have collaborated regarding the use of robotics in welfare services? (3) In your view, which stakeholders are missing from the current public discussion on the use of robotics in welfare services? (4) In your view, which stakeholders should be involved in the development of products and services related to the use of robotics in welfare services? Again, these were multiple-choice questions and the participants were allowed to select as many options as they wished. Each response was treated as a single variable in the analysis. If a participant selected an option, the response was marked as 1, and if the participant did not select an option, it was marked as 0. A pairwise t-test was used to compare the responses of the two groups.

For each question, the number of responses was different because not all respondents answered the whole questionnaire. It is possible that respondents skipped questions that they did not wish to answer. Some people had filled in only their background information so they were removed from the analysis because we wanted to include as many responses as possible. The questions, therefore, had differing numbers of respondents.

5 Results

The results section is divided by topic such that the questions relating to the stakeholders' use of robots within the ecosystem will be discussed first and then those relating to collaboration and knowledge sharing.

5.1 Use of Robots Within the Ecosystem

Which of the following factors hinder the introduction of robots into welfare services in Finland?

For this question, there were 185 answers (110 from service actors and 75 from R&D actors). On average, each person selected 7.2 of the 26 options. Figure 1 shows the mean values ± standard error of the means (SEMs) for each of the options and Table 2 shows the results of the pairwise comparisons.

INSERT FIGURE 1. Response options as selected for the question: 'Which of the following factors hinder the introduction of robots into welfare services in Finland?'

INSERT TABLE 2. Pairwise comparison of factors, reported with t-value and level of significance

If we look at the responses, three factors seem to have the greatest effect in 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. These differences between the two groups were probably due to the professions of the participants, that is, people working in municipal care services are less likely to consider funding models or robot technology development.

Which of the following factors accelerate the introduction of robots into welfare services in Finland?

For this question, 181 responses were received (108 from service actors and 73 from R&D actors). On average, each person selected 7.5 of the 25 options when answering this question. Figure 2 shows the mean values ± SEMs for each option, and Table 3 shows the results of the pairwise comparisons.

INSERT FIGURE 2. Response options as selected for the question: 'Which of the following factors will accelerate the introduction of robots into welfare services in Finland?'

INSERT TABLE 3. Pairwise comparison of factors

Judging by the responses, it would seem that respondents think many options have the potential to accelerate the introduction of robots in welfare services, but a 'clear winner' cannot 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 seems to be considered the most important factor in speeding up the introduction of robots. When piloting, a piece of technology (e.g. a robot) is used for a short period of time to see how it might fit in the context and what kind 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 (Prime Minister's Office (2019).

5.2 Collaboration and knowledge sharing

With whom (in your profession) have you discussed the use of robots in welfare services?

For this question, a total of 220 answers were received (127 from service actors and 93 from R&D actors). On average, each person selected 3.7 of the 18 options in responding to this question. Figure 3 shows the mean values ± SEMs for each option and Table 4 shows the results of pairwise comparisons.

INSERT FIGURE 3. Response options as selected for the question: 'With whom (in your profession) have you discussed the use of robots in welfare services?'

The pairwise comparison for each variable is presented in Table 4. In general, the results show that R&D actors have discussed the use of robots in welfare services with a greater variety of stakeholders than the service actors.

INSERT TABLE 4. Pairwise comparison of each factor

Based on the responses, it would seem that the service actors have discussed the use of robots in welfare services with fewer stakeholder groups than the R&D actors. However, both groups have discussed the use of robots within their own work community. Thus, it would appear that the topic is being discussed in the work place but not elsewhere.

With whom you have collaborated regarding the use of robotics in welfare services?

A total of 219 answers were received for this question (125 from service actors and 94 from R&D actors). On average, each person selected 2.3 of the 17 options. Figure 4 shows the mean values ± SEMs for each option and Table 5 shows the results of the pairwise comparisons.

INSERT FIGURE 4. The selection of response options to the question: 'With whom you have collaborated regarding the use of robotics in welfare services?'

INSERT TABLE 5 Pairwise comparison of each factor

Overall, collaboration regarding the use of robots in welfare services is still rare. R&D actors have collaborated significantly more than the service actors.

In your view, which stakeholders are missing from the current public discussion on the use of robotics in welfare services?

For this question, a total of 196 answers were received (112 from service actors and 84 from R&D actors). On average, each person selected 3.1 of the 18 options when responding to this question. Figure 5 shows the mean values ± SEMs for each option and Table 6 shows the results of the pairwise comparisons.

INSERT FIGURE 5. The selection of response options to the question: 'In your view, which stakeholders are missing from the current public discussion on the use of robotics in welfare services?'

INSERT TABLE 6. Pairwise comparison of each factor

Based on the results, the two most important groups that should be involved in the discussion are private persons who use robots in their homes and the customers of services that utilize robots. The R&D actors, in particular, thought that private persons who use robots in their homes should be involved in the discussions.

In your view, which stakeholders should be involved in the development of products and services related to the use of robotics in welfare services?

For this question, a total of 207 answers were received (120 from service actors and 87 from R&D actors). On average, each person selected 7.8 response of the 17 options for this question. Figure 6 shows the mean values ± SEMs for each option and Table 7 shows the results of pairwise comparisons.

INSERT FIGURE 6. The selection of response options to the question: 'In your view, which stakeholders should be involved in the development of products and services related to the use of robotics in welfare services?'

INSERT TABLE 7. Pairwise comparison of each factor

The responses to this question revealed, first, that both the users of robots (i.e., private persons who use robots in their homes and customers of services that utilize robots) and the professionals who use robots should be involved more. Second, a greater range of options were chosen in answering this question than in any other question in the collaboration section. Third, these responses indicate the important role of researchers in the public discussion— they are the most likely to provide valid information based on empirical knowledge. Again, the R&D actors seemed to think that more stakeholders are needed to take part in the discussion than the service actors did.

6 Discussion

Regarding our research question about key factors in the dynamics of an emerging care robotics innovation ecosystem in welfare services, we found that a wide range of actors are needed. According to our results, the existing collaborative networks and the stakeholders that respondents think should be involved, are all very much focused on micro-level actors, such as workmates and professional and private robot users rather than policy-level actors.

An innovation ecosystem in robots in welfare services has been almost non-existent in Finland. Based on the responses to our survey, it seems that the group 'R&D actors', have discussed robots and collaborated more than the group 'service actors'. R&D actors seem to think that more stakeholders need to take part in the discussions. While this is somewhat to be expected due to the positions held by the respondents in this group, it is the service actors, from the municipalities and hospital districts in Finland, who will make the decisions regarding the acquisition of robots. How to strengthen the role of the service actors and how to get them to play a more active role in the development of robotic services are important considerations.

In order to understand the innovation ecosystem, and which actors are involved and which are missing, we asked the respondents with whom they had discussed the use of robots in the welfare services. The first step towards collaboration is often an informal discussion. The results showed that the respondents had been discussing robots in their own work communities, with officials and decision-makers, and with robotic professionals. Discussions about robots do not yet seem to have led to any true collaboration; it appears that collaboration is even rarer than discussion.

Defining ecosystem boundaries is generally challenging (Rinkinen and Harmaakorpi, 2018). Our study highlights the fact that innovation ecosystems include various relevant actors, also users. The role of the innovation ecosystem is not only a collaborative production system but also a system of use that creates knowledge for production.

The responses clearly indicate that the users of robots (both private persons who use robots in their homes and customers of services that utilize robots) should be involved in public discussions about using robots in the welfare services and should be involved in the development of services, both new and existing, utilizing robots. Sprenger and Mettler (2015) investigated service robots and they highlight that current research is usually concerned with the technical aspects of a robot, but that there is a lack of research on blending service robots into a human-centred context. If service robots are to be used in the human environment, they must meet various requirements, but this human-centred context tends to be missing from research and there is a failure to consider the introduction of service robots in different contexts. A major factor emerging from our results is that individual users are currently not drawn into the discussion, although the respondents considered them the most important group to be involved in the development work. To recap, the quite low amount of responses in Figures 3 and 4 reflects the current situation in the innovation ecosystem; the actors have not discussed or collaborated with many people. Overall, the number of selected options was quite low, varying, however, according to the question. This could be partly because the respondents viewed the situation from the point of view of their own expertise. The research question concerning factors that might accelerate the introduction of robots drew similar responses to many of the options; it was therefore not possible to identify the most important factors. However, the R&D actors seemed to think that the piloting culture in Finland can accelerate the process. The importance of a piloting culture is in line with the concept of 'niche' development in the transition of a system (e.g. Kemp, Schot, & Hoogma, 1998; Schot and Geels, 2008). These experimental projects in real-life contexts are seen to be critical as they bring together actors from various environments in shared networking and learning activities (Bugge, Coenen, Marques, & Morgan, 2017).

This study exposed three main factors that hinder the introduction of robots: the care culture, resistance to change and fear of robots. These hindering factors are largely attitudinal and based on existing path-dependencies rather than on technological limitations. The routine behaviour of organizations can lead to political, structural and cognitive lock-ins, and these can be a barrier to change (Grabher, 1993). Decisions made in the past may have an effect at the unconscious level, even if the need for change is consciously recognised (Vigoda-Gadot, Shoham, Ruvio, & Schwabsky, 2008). Thus, we can say that the essential factors in the success of the ecosystem are not technical but social. This highlights the need to recognize that social and technical aspects must co-evolve and re-adjust accordingly (see Geels, 2005) in the development of innovation ecosystems.

Given the strong role of the public sector in Finnish care services, we emphasize that 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, Pekkarinen, Hennala, Melkas, 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.

However, it must be noted that we study the birth-phase of the ecosystem and therefore cannot predict its future dynamics: for instance, which actors' roles will become important in the later phases of the ecosystem. Furthermore, the study gathers only a limited opinion of the actors. However, it is evident that robotics will become increasingly important in all fields of society and that the robot ecosystem will continue to emerge. The topic is already taken seriously at the national level and a national robot strategy is already in progress.

7 Conclusions

In this paper we have analysed the dynamics of the emerging care robotics ecosystem in the Finnish welfare services. The results show that a wide range of actors are needed in the ecosystem: especially the role of micro-level actors, such as workmates and professional and private robot users, is important. In particular, research and development seem to be open to new stakeholders in the robot ecosystem and highlight the importance of the collaboration between actors. The ecosystem is dynamic, and the dynamics in the ecosystem seem to be largely based on social and cultural issues. Piloting culture could accelerate the introduction of robotics and ecosystem growth in society. The hindering factors are also largely attitudinal and based on existing path-dependencies rather than on technological limitations.

On the basis of the results, the ecosystem appears to be both 'a target for managerial action' and 'self-evolving', in accordance with what Ritala & Almpanopoulou (2017, p. 41) called for; 'The unique features of purposeful design and evolutionary nature may take the innovation ecosystem concept viable for examining real world phenomena in both of these important respects'. 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 of purposeful action and management, for instance in terms of having users participate (and also in terms of policy actions, related for instance to funding instruments).

As a contribution to innovation research more generally, this study has provided a concrete example of a service innovation ecosystem where services are produced through intertwining of technologies and humans, and where both market- and policy-driven forces affect the emergence of the ecosystem. The results highlight the importance of fostering the collaboration between service producers and research and development actors, as well as with other groups, which, perhaps a bit surprisingly, was especially highlighted by the R&D actors, as compared to the service actors.

It is notable that both hindering and accelerating factors in the implementation of robots in welfare services are clearly related to social and cultural issues, like habits and attitudes. The role of individual users in the innovation ecosystems should be strengthened, and the question of how to turn the informal discussion into more concrete collaboration should be considered. Future studies should focus on this topic from the perspective of other countries, to shed light on possible differences and similarities across countries.

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Table 2. Pairwise comparison of factors, reported with t-value and level of significance

Factors that hinder the introduction	**Group**	**t-test**
Care culture	R&D actors = service actors	ns.
Legislation	R&D actors = service actors	ns.
Innovation policy	R&D actors = service actors	ns.
Lack of funding models for acquisition and innovation	R&D actors > service actors	$t(183)=2.64, p<0.01$
Social structure	R&D actors = service actors	ns.
Piloting culture	R&D actors = service actors	ns.
Technology availability	R&D actors > service actors	$t(183)=2.22, p<0.05$
Lack of domestic robot technology development	R&D actors > service actors	$t(183)=4.24, p<0.0001$
Lack of international business in robotics	R&D actors = service actors	ns.
Lack of domestic business in robotics	R&D actors = service actors	ns.
Service structures	R&D actors = service actors	ns.
Trends in services (e.g., individualization, service integration)	R&D actors > service actors	$t(183)=2.14, p<0.05$
Interest in technology	R&D actors = service actors	ns.

Information security	R&D actors = service actors	ns.
Technology trends (e.g., IoT, AI)	R&D actors = service actors	ns.
Readiness of workplaces for technology introduction (e.g., orientation)	R&D actors = service actors	ns.
Professional and continuing training	R&D actors > service actors	$t(183)=3.07$, $p<0.01$
Resistance to change	R&D actors = service actors	ns.
Attitudes towards the elderly	R&D actors = service actors	ns.
Attitudes of the elderly	R&D actors = service actors	ns.
Research knowledge	R&D actors = service actors	ns.
Ethical viewpoint	R&D actors = service actors	ns.
Media actions	R&D actors = service actors	ns.
Fear of robots	R&D actors = service actors	ns.
International diffusion of robots	R&D actors = service actors	ns.
Other	R&D actors > service actors	$t(183)=2.84$, $p<0.01$

Table 3. Pairwise comparison of factors

Factors that accelerate the introduction	**Group**	**t-test**
Care culture	R&D actors = service actors	ns.
Legislation	R&D actors = service actors	ns.
Innovation policy	R&D actors = service actors	ns.
Funding models for acquisition and innovation	R&D actors = service actors	ns.
Social structure	R&D actors = service actors	ns.
Piloting culture	R&D actors > service actors	$t(179)=3.39$, $p < 0.01$
Technology availability	R&D actors = service actors	ns.
Domestic robot technology development	R&D actors = service actors	ns.
International business in robotics	R&D actors > service actors	$t(179)=2.03$, $p < 0.05$
Domestic business in robotics	R&D actors > service actors	$t(179)=2.07$, $p < 0.05$
Service structures	R&D actors = service actors	ns.
Trends in services (e.g., individualization, service integration)	R&D actors = service actors	ns.
Interest in technology	R&D actors = service actors	ns.
Information security	R&D actors = service actors	ns.

Technology trends (e.g., IoT, AI)	R&D actors = service actors	ns.
Readiness of workplaces for introduction of technology (e.g. orientation)	R&D actors = service actors	ns.
Professional and continuing training	R&D actors = service actors	ns.
Readiness to change	R&D actors = service actors	ns.
Attitudes towards the elderly	R&D actors = service actors	ns.
Attitudes of the elderly	R&D actors = service actors	ns.
Research knowledge	R&D actors = service actors	ns.
Ethical viewpoint	R&D actors > service actors	$t(179)=2.86$, $p < 0.01$
Media actions	R&D actors = service actors	ns.
International diffusion of robots	R&D actors = service actors	ns.
Other	R&D actors = service actors	ns.

Table 4. Pairwise comparison of factors

Discussion partner	**Response group**	**t-test**
Own work community	R&D actors > service actors	$t(218) = 3.48$, $p < 0.01$
Professionals who use robots	R&D actors > service actors	$t(218) = 4.98$, $p < 0.001$
Private persons who use robots in their homes	R&D actors > service actors	$t(218) = 2.37$, $p < 0.05$
Customers of services that utilize robots	R&D actors > service actors	$t(218) = 2.75$, $p < 0.01$
Municipal office-holder and/or decision-maker	R&D actors = service actors	ns.
National office-holder and/or decision-maker	R&D actors > service actors	$t(218) = 4.67$, $p < 0.001$
International office-holder and/or decision-maker	R&D actors > service actors	$t(218) = 4.38$, $p < 0.001$
Trade union/labour market organization	R&D actors > service actors	$t(218) = 3.22$, $p < 0.01$
Robots' manufacturer, importer, marketer or subcontractor	R&D actors > service actors	$t(218) = 4.01$, $p < 0.001$
Development companies or idea- and company hatcheries	R&D actors > service actors	$t(218) = 6.14$, $p < 0.001$
Sponsors	R&D actors > service actors	$t(218) = 3.78$, $p < 0.001$
Researchers	R&D actors > service actors	$t(218) = 7.61$, $p < 0.001$
Teachers and students	R&D actors > service actors	$t(218) = 4.88$, $p < 0.001$

Designers	R&D actors > service actors	$t(218) = 4.01, p < 0.001$
The media	R&D actors > service actors	$t(218) = 4.39, p < 0.001$
Social media	R&D actors > service actors	$t(218) = 4.01, p < 0.001$
Other	R&D actors = service actors	ns.
None	R&D actors < service actors	$t(218) = 3.91, p < 0.001$

Table 5. Pairwise comparison of each factor

Collaboration partner	**Group**	**t-test**
Own work community	R&D actors > service actors	$t(217) = 4.05$, $p < 0.001$
Professionals who use robots	R&D actors > service actors	$t(217) = 5.57$, $p < 0.001$
Private persons who use robots in their homes	R&D actors > service actors	$t(217) = 2.45$, $p < 0.05$
Customers of services that utilize robots	R&D actors > service actors	$t(217) = 2.73$, $p < 0.01$
Municipal office-holder and/or decision-maker	R&D actors > service actors	$t(217) = 2.44$, $p < 0.05$
National office-holder and/or decision-maker	R&D actors > service actors	$t(217) = 4.47$, $p < 0.001$
International office-holder and/or decision-maker	R&D actors > service actors	$t(217) = 2.58$, $p < 0.05$
Trade union/labour market organization	R&D actors > service actors	$t(217) = 4.05$, $p < 0.001$
Robots' manufacturer, importer, marketer or subcontractor	R&D actors = service actors	ns.
Development companies or idea- and company hatcheries	R&D actors > service actors	$t(217) = 4.31$, $p < 0.001$
Sponsors	R&D actors > service actors	$t(217) = 3.37$, $p < 0.01$
Researchers	R&D actors > service actors	$t(217) = 7.15$, $p < 0.01$

Teachers and students	R&D actors > service actors	$t(217) = 4.98$, $p < 0.001$
Designers	R&D actors > service actors	$t(217) = 2.64$, $p < 0.01$
The media	R&D actors > service actors	$t(217) = 3.59$, $p < 0.001$
Other	R&D actors = service actors	ns.
None	R&D actors < service actors	$t(217) = 5.21$, $p < 0.001$

Table 6. Pairwise comparison for each factor

Missing from discussion	**Group**	**t-test**
Own work community	R&D actors = service actors	ns.
Professionals who use robots	R&D actors = service actors	ns.
Private persons who use robots in their homes	R&D actors > service actors	$t(194) = 2.25, p < 0.05$
Customers of services that utilize robots	R&D actors = service actors	ns.
Municipal office-holder and/or decision-maker	R&D actors = service actors	ns.
National office-holder and/or decision-maker	R&D actors = service actors	ns.
International office-holder and/or decision-maker	R&D actors = service actors	ns.
Trade union/labour market organization	R&D actors = service actors	ns.
Robots' manufacturer, importer, marketer or subcontractor	R&D actors = service actors	ns.
Development companies or idea- and company hatcheries	R&D actors = service actors	ns.
Sponsors	R&D actors > service actors	$t(194) = 2.20, p < 0.05$
Researchers	R&D actors > service actors	$t(194) = 2.39, p < 0.05$
Teachers and students	R&D actors = service actors	ns.

Designers	R&D actors = service actors	ns.
The media	R&D actors = service actors	ns.
Social media	R&D actors = service actors	ns.
Other	R&D actors > service actors	$t(194) = 2.51, p < 0.05$
All necessary parties are involved	R&D actors = service actors	ns.

Table 7. Pairwise comparison of factors

Should be involved	**Group**	**t-test**
Own work community	R&D actors > service actors	$t(205) = 3.91, p < 0.001$
Professionals who use robots	R&D actors = service actors	ns.
Private persons who use robots in their homes	R&D actors > service actors	$t(205) = 2.81, p < 0.05$
Customers of services that utilize robots	R&D actors > service actors	$t(205) = 2.82, p < 0.01$
Municipal office-holder and/or decision-maker	R&D actors = service actors	ns.
National office-holder and/or decision-maker	R&D actors = service actors	ns.
International office-holder and/or decision-maker	R&D actors > service actors	$t(205) = 3.22, p < 0.01$
Trade union/labour market organization	R&D actors > service actors	$t(205) = 2.98, p < 0.01$
Robots' manufacturer, importer, marketer or subcontractor	R&D actors = service actors	ns.
Development companies or idea- and company hatcheries	R&D actors > service actors	ns.
Sponsors	R&D actors > service actors	$t(205) = 2.21, p < 0.05$
Researchers	R&D actors > service actors	$t(205) = 3.63, p < 0.001$

Teachers and students	R&D actors > service actors	$t(205) = 2.64, p < 0.01$
Designers	R&D actors > service actors	$t(205) = 2.85, p < 0.01$
The media	R&D actors = service actors	ns.
Social media	R&D actors > service actors	$t(205) = 2.38, p < 0.05$
Other	R&D actors = service actors	ns.