Knowledge brokerage needs in building care robotics innovation ecosystems and networks

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DOI: 10.1080/09654313.2021.1998386

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Abstract

In the ecosystem and network perspectives on innovation, cooperation between various actors is seen as essential to innovation. Because of several factors known to hinder cooperation, the literature has pointed out the need for knowledge brokerage functions. This paper investigates knowledge brokerage needs in building care robotics innovation ecosystems and networks in Finland. The research questions are as follows: What are macro-, meso- and micro-level brokerage needs, functions and roles in care robotics innovation ecosystems and networks, and what kinds of knowledge should be brokered at these different levels? The data were collected with multilevel interviews, including interviewees representing different interests and fields of expertise. Based on the results, there is a need for brokerage functions in emerging ecosystems and networks to create operational conditions, bring disparate actors together, manage innovation processes, create learning possibilities and share best practices. However, the brokerage needs to vary by level, indicating that the functions and roles of the brokers and brokered knowledge may be emphasised differently. At the macro level, system-level knowledge is needed, at the meso level, knowledge related to innovation process management and user knowledge is needed, and at the micro level, the need for experimental and tacit knowledge is highlighted.

Keywords: Knowledge, brokerage, innovation ecosystem, innovation network, care robotics

Introduction

Digitalisation increases and diversifies both innovation activities and knowledge, emphasising the need for knowledge brokerage to utilise collaboration and innovation opportunities. Digitalisation plays a major role in renewing care services, and high hopes have been placed on digitalisation and technological innovations, such as electronic health (e-health), various types of health and safety monitoring, home automation and robotics (Pekkarinen & Melkas, 2017). There are several triggers for implementing these technologies, such as an ageing population and an increasing need for a care workforce. The introduction of robots into society implies a profound socio-technical transition where the simultaneous development of technologies and new service operations may cause challenges (Pekkarinen et al., 2020). Technological development does not take place in a 'vacuum'; it is also about the interactions and entanglement of technical artefacts with organisations, actors, structures and social practices (Geels, 2005; Fraedrich et al., 2015).

Developing successful welfare services and products requires a combination of knowledge from both the welfare sector and production. In such a process, the actors may have little knowledge in common, but their collaboration is required to bring together a number of competences and cultures (Pekkarinen & Harmaakorpi, 2006; Del Giudice et al., 2017). Knowledge brokerage may respond to this challenge of bringing diverse actors together and facilitating the emergence of knowledge combinations. The need for studies concerning the coevolution of robots and services as emerging innovation ecosystems has been emphasised by Pekkarinen et al. (2020). Care robots in Finland have been piloted in various use environments, but when considering their wider implementation and use, there are still few studies on the subject. Pekkarinen et al. (2020) found that knowledge is essential in the emergence of a care robotics innovation ecosystem and knowledge-related issues are often related to the accelerators and barriers affecting an ecosystem's or network's emergence and development. The variety of stakeholders and their roles in an innovation ecosystem or network also has an impact on other knowledge management needs.

In the present study, we focus on the knowledge brokerage needs in building care robot innovation ecosystems, with Finland being the example case (see also Pekkarinen et al., 2020). We discuss knowledge brokerage in building innovation ecosystems and briefly present the current use of care robots and the status of the national care robotics innovation ecosystem in welfare services. Our empirical study analyses knowledge brokerage needs by using multilevel interview data collected in 2018–2019. The interviews are analysed to provide an understanding of the knowledge brokerage needs related to building care robotics innovation ecosystems and networks. The term 'ecosystems' is also used in a plural sense because the results of our study may be utilised at both the local and national levels. Our main research questions are as follows: (1) What are macro-, meso- and micro-level knowledge brokerage needs, tasks and roles in emerging care robotics innovation ecosystems and networks? (2) What kinds of knowledge should be brokered at these different levels?

Theoretical Background

Knowledge brokerage in building innovation ecosystem and networks

Studies on social networks have shared the notion that innovation can be created by transferring and combining the ideas, knowledge and artefacts held by different individuals, organisations or institutions (Granovetter, 1985; Burt, 2004). Integrating knowledge in networks brings forth numerous challenges because of the diversity of network members (Boschma, 2005; Broekel & Boschma, 2012). If this diversity is not properly managed, it may create barriers for the creation and transfer of knowledge and, thus, for innovations. To transcend these barriers and ensure knowledge availability and accessibility to all in networks, the central role of knowledge brokers has been recognised in several studies (e.g., Howells, 2006; Parjanen, 2012; Cummings et al., 2019; Newman et al., 2020).

A great number of functions can be attributed to knowledge brokers. According to Burt (2004), brokerage (or brokering) could occur by making people on both sides of a structural hole aware of the interests and difficulties of the other group, transferring best practices, drawing analogies between groups ostensibly irrelevant to one another and making syntheses of knowledge interests. Howells (2006) identified the following functions: foresight and diagnostics; scanning and information processing; knowledge processing and combination/recombination; gatekeeping and brokering; testing and validation; accreditation; validation and regulation; protecting the results; commercialisation; and evaluating the outcomes. Van Eerd et al. (2016) found that although knowledge broker approaches differ based on stakeholders' desired outcomes, they have practices in common, including disseminating knowledge, linking/networking, adapting/translating knowledge, acquiring knowledge and enhancing capacity.

Melkas and Harmaakorpi (2008) examined brokerage functions in regional innovation networks (see also Kangas & Aarrevaara, 2020), here focusing on data, information and knowledge quality and their relation to brokerage functions in such networks. According to them, the practical tasks for a broker could contain a definition of the operational logic of the innovation network regarding data, information and knowledge; the identification of the necessary flows of data, information and knowledge, as well as the potential bottlenecks in these flows; identification of the roles of actors in relation to data, information and knowledge and a consideration of the needs of the different roles considering the strategic versus tactic or operational gains that can be brought about by a good level of data, information and knowledge quality; and the identification of the necessary data, information and knowledge quality for different types of materials, conversion phases and processes (Melkas and Harmaakorpi 2008).

van Lente et al. (2003) listed three basic functions for brokers: demand articulation, network composition and innovation process management. Demand articulation comprises the diagnosis and analysis of a problem and the articulation of the needs of the organisation. Network composition refers to making external relations available to an organisation. This means the scanning, scoping, filtering and matchmaking of the sources of complementary assets, such as knowledge, material and funding (Howells, 2006). Innovation process management is the process of creating an atmosphere that stimulates knowledge sharing, enabling a fair distribution of costs and benefits between innovation network members and anticipating and resolving potential conflicts between members (Batterink et al., 2010). Brokers are also defined as the glue keeping the network together by taking care of day-to-day network management issues, enhancing trust and resolving conflicts (Kingsley & Malecki, 2004). Since the studies were first published, knowledge brokering has been on the rise in various spheres of knowledge societies with the general aim of improving the interaction between knowledge production and use (Leino et al., 2018). For example, Duncan et al. (2020) identified underexplored aspects of brokering expertise, such as transdisciplinary skills and expertise, 'absorptive' uncertainty management and knowledge translation practices.

Boari and Riboldazzi (2014) adopted Burt's (2004) typology and recognised four functions through which a broker can create value: (a) make intermediated actors aware of the interests and problems of the other side, which is a transcoding function; (b) transfer best practices; (c) draw analogies between intermediated actors that have not been visible or were not considered relevant to them; and (d) try to create new beliefs and behaviours by combining the elements derived from the brokerage position, which is a synthesis function. Thus, drawing analogies and syntheses is more challenging for brokers, particularly when the mediated groups are more heterogeneous. In this situation, it is more difficult to find analogies and, therefore, more difficult to create new knowledge through combinations, but this situation also offers greater opportunities for innovation.

Knowledge brokers have mainly been studied at the interfirm level, that is, an external brokerage linking two or more nonrelated firms to transfer and recombine knowledge between them (e.g., Hargadon, 1998; Hargadon & Sutton, 1997; Boari & Riboldazzi, 2014). Knowledge brokerage at the intraorganisational level has been emerging in practice. Internal brokers have been defined as '*individuals who provide connections between communities of practice, transfer elements of one practice into another, enable coordination, and through these activities can create new opportunities for learning*' (Wenger, 1998, p. 109). The need for internal brokerage has been acknowledged in the literature. Cillo (2005) proposed that when knowledge is very complex and there is no common culture or language, internal knowledge brokers can enhance the sharing and use of this knowledge. Also, the case study of a telecommunications company recognised the need for internal brokers acting in a bridging role inside the organisation to connect different employees, groups or departments, make them aware of the interests and challenges of the other group and transfer best practices (Parjanen, 2012). It is also possible that there is a need for more than one kind of brokerage at the same time. Parjanen and Hyypiä (2018) found that the building of a regional innovation platform included both internal and external brokerage.

Brokerage functions are often discussed without distinguishing among them, considering them a single uniform group. However, brokers can be grouped in different manners based on their activities, thereby changing the nature of knowledge transfer and implications of innovation (Boari et al., 2017). Gould and Fernandez (1989) identified five different brokerage roles: coordinator, gatekeeper, representative, itinerant, and liaison. When an actor brings two persons from her or his own groups in contact with each other, she or he is a coordinator. This role is completely internal. A gatekeeper receives external knowledge by collecting knowledge from outside to transfer this to her or his own group. A representative transfers knowledge from her or his own group to an actor in another group, hence representing her or his own group to the outside. An itinerant broker transfers knowledge between individuals who belong to the same group, which is not the group of the itinerant broker. Finally, a liaison acts in a triadic relationship in which none of the actors belong to the same group. Here, this actor's role is to link distinct groups.

Parjanen, Melkas and Uotila (2011) also defined five central roles for knowledge brokers: policy executor, creative actor, crosser of distances, shaper of organisations and sniffer of the future. These roles could be played in various places or interfaces in the innovation ecosystem or network, as depicted in Figure 1. The authors noted that successful brokerage requires a holistic approach to the entire innovation processes and their wider environments.

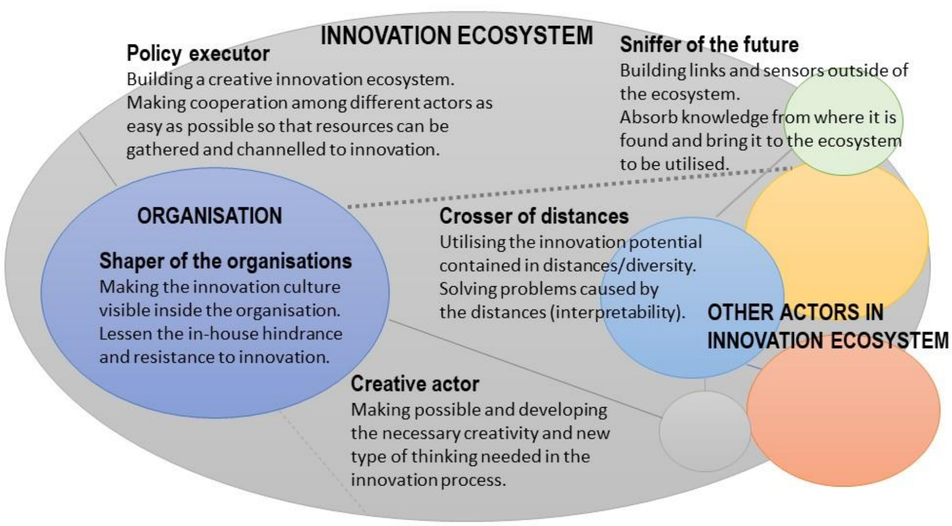

Figure 1. Different knowledge brokerage roles in innovation ecosystems

The application of different brokerage functions and roles depends on the requirements of the innovation network in the different phases of its development (Boon et al., 2008) and the composition of the network in terms of the tie density and strength (Winch & Courtney, 2007). In addition, brokerage roles may differ for various actors (Gould & Fernandez, 1989) and for the same actor at different times (Graf, 2011). For example, the findings of Bornbaum et al. (2015) revealed significant heterogeneity in the settings, interventions and role descriptions of the brokers.

Knowledge brokers in health care services have been the focus in a number of studies (e.g., Dagenais et al., 2015; Bornbaum et al., 2015; Glegg & Hoens, 2016), but brokerage studies related to technology use in care services are rare. The present study focuses on a combination of roles for knowledge brokers as identified by Gould and Fernandez (1989) in their prominent study and those identified by Parjanen et al. (2011). This combination contains characteristics that suit the novelty of care robotics as technologies that start to be used in care services.

The Context of the Study: Care Robots and the Care Robotics Innovation Ecosystem in Finland

The societal and systemic levels of care robot use

In this study, the focus is on care robotics as a subcategory of service robotics[1]. Care robots are service robots that are utilised in welfare services. Their tasks are quite similar to other service robots (Okamura et al., 2010; see also Creswell et al., 2018). The service robots utilised in welfare services may help observe health behaviours, offer support for the elderly and their caregivers in daily tasks and provide companionship (Wu et al., 2012). Their actual integration in care systems varies greatly, and new types are constantly being developed (e.g., for personal hygiene, cognitive therapy and rehabilitation).

The societal and systemic levels related to the use of care robots are still rarely discussed despite efforts to advance the use of robots in welfare services and various countries' initiatives to produce robotisation strategies for those services. New technologies such as robots contribute to broader societal changes with their constant 'negotiations' with markets, policies, science, infrastructures, user preferences and thinking models—thus, it is 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 & Rotmans, 2010). Therefore, a wider and deeper understanding of the societal and systemic levels is crucial (Pekkarinen et al., 2020).

To the best of our knowledge, studies of care robotics innovation ecosystems or networks are very rare. A view of care service ecosystems for ambient assisted living (AAL) was presented by Camarinha-Matos et al. (2015). An AAL ecosystem can involve (in addition to senior citizens) a combination of formal and informal care networks. Camarinha-Matos et al. (2015, p. 616) defined an AAL ecosystem as '*a care and assistance community of interacting entities, both organisations and individuals, with the purpose of providing care and assistance services to senior citizens, who are themselves special members of the ecosystem. This community operates according to cooperation agreements and adopts common operating principles and ICT support infrastructures and mechanisms to effectively provide value added services and dynamically adjust to the evolving needs of its members, and thus represents a complex socio-technical*

[1]Robots can be divided into two categories: industrial robots and service robots (International Federation of Robotics [IFR], 2012). Service robots are used by service providers or individual consumers. Service robots exist in many forms, sizes and purposes.

system'. This type of ecosystem has structural, componential, functional and behavioural dimensions. The views of Camarinha-Matos et al. (2015) did not focus on robots in particular, but they also emphasised the need to understand existing organisational structures—entities that operate and communities that exist on a regional or local basis, implying that focusing on regional or local AAL ecosystems is realistic: '*Even within one (small) geographical area we might foresee the emergence of different AAL ecosystems based on different criteria (e.g., cultural, interests, economic level). Certainly there are major stakeholders (e.g., infrastructure operators, special service providers, insurance companies, etc.) that operate at [the] national (or international) level. But this fact is not an obstacle for a model based on local ecosystems, since such stakeholders might participate in several local ecosystems'* (Camarinha-Matos et al., 2015, pp. 617–618). This is important to keep in mind when considering knowledge brokerage, which is needed at different levels.

Sprengler and Mettler (2015) investigated service robots (not in the care domain), concluding that existing research usually concerns the technical aspects of the robot itself, but there remains a lack of context-specific research on service robots. The system level is addressed in terms of human work environments and existing information technology landscapes. The authors highlighted the need for a multidisciplinary approach; as well as the corresponding requirements to introduce service robots into everyday life and fully leverage the service robots' potential. Severinson-Eklundh et al. (2003) focused on office environments but concluded that addressing only the primary user in service robotics is unsatisfactory and that the focus should be on the setting, activities and social interactions of the group of people for whom the robot will be used. Čaić, Odekerken-Schröder and Mahr (2018) studied robots in elderly care networks and noted that robots have several roles in the value networks of elderly care, and these networks can have both strong value co-creation and co-destruction potential.

Ecosystems are networks gathering complementary resources and involving cooperation, competition and interdependence (Adner & Kapoor, 2010). The innovation ecosystem concept (e.g., Adner & Kapoor, 2010), which draws on Moore's (1993) concept of the business ecosystem, has increasingly gained ground in the literature on strategy, innovation, entrepreneurship and regional development (de Vasconcelos Gomes et al., 2018; Rinkinen & Harmaakorpi, 2018; Ritala & Gustafsson, 2018). 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 ecosystem concept has been perceived as having a complex, self-organising and self-renewing nature. However, Oh et al. (2016) saw an innovation ecosystem as a designed entity instead of an evolved one. 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 with the simultaneous roles of service producer and organiser. With this in mind, it is important to understand which parts of the innovation ecosystem can and should be engineered and how and which parts perhaps are self-organised or coevolved (Ritala & Gustafsson, 2018).

The Finnish care robotics innovation ecosystem

The results of a survey conducted among relevant Finnish stakeholders (Pekkarinen et al., 2020) showed that a variety of stakeholders are needed in care robotics innovation ecosystems. In particular, research and development actors seemed to be open to new stakeholders entering the ecosystem, highlighting the importance of collaboration between actors. The ecosystem was dynamic, and the dynamics in the ecosystem seemed to be largely based on social and cultural issues. The culture of piloting in Finland was accelerating the introduction of robotics and ecosystem growth in society, but factors such as fears and resistance to change were hindering its development. The hindering factors were largely attitudinal and based on existing path dependencies rather than on technological limitations.

Pekkarinen et al., 2020) concluded that the ecosystem appeared to be both 'a target for managerial action' and 'self-evolving', in accordance with what Ritala and 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 was self-evolving regarding accelerating and hindering 'forces', as well as mutual collaboration and adjustment between actors, but still, it seemed 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, e.g., to funding instruments). Based on the results of Pekkarinen et al., 2020), there are a number of arenas in the innovation ecosystem where knowledge brokerage could facilitate, for example, overcoming attitudinal hindering factors.

Materials and Methods

Data collection

The current study uses semistructured interviews and focus group interviews as a research method. Semistructured interviews were chosen as the research method because of the flexibility of the interview process. The present research is interested in what the interviewees say, but also in how they frame and understand issues and events, which means studying the things that the interviewee views as important in explaining and understanding events and forms of behaviour (Bryman, 2008). In addition, two focus group interviews were conducted. In focus group interviews, people ask questions, exchange anecdotes and comment on each other's experiences and points of view. In this way, it is possible to explore which issues are important and which are ignored, thus revealing the interviewees' priorities (Rabiee, 2004).

To obtain multi-faceted knowledge from different levels of the ecosystem, 10-12 individuals representing each level were interviewed. In other words, the 33 interviewees represented the following:

- The micro level: 10 individuals participated in two focus group interviews (professional caregivers and care managers)
- The meso level (organisational and community level): 12 individuals participated in 10 semistructured interviews [representatives of companies, interest organisations or associations of social and healthcare professionals, interest organisations or associations of end users/ citizens (older people), organisers or providers of public social and healthcare services and educational institutions for educating professionals in social and healthcare or welfare technology fields]

- The macro-level (societal level): 11 individuals participated in nine semistructured interviews (representatives of political decision-makers, research organisations, insurance organisations, funding organisations and the media).

There were two to three participants per aforementioned group. This set of interviews unearthed a multifaceted picture of the situation in Finland. We focused on people whose work was related to the social and healthcare sector or robotics at three levels, ranging from professional caregivers to decision-makers. End users (the clients of services) were beyond the scope of the current study. The meso-level representatives were chosen because of their position as intermediaries at the interface between the micro-level representatives, care professionals and managers and the macro level of decision-makers. The meso-level representatives were in contact with the practice but were also active in networking and operating in the context of broader societal issues.

We asked the interviewees to freely describe the current situation in the field of care robotics in Finland and their collaboration networks and partners and to describe the information and knowledge level of the actors in this field, along with what they should know and why and who should provide the information and knowledge. We asked their views about good practices and models for networking on these issues. We also asked the interviewees about hindering and advancing elements of robot implementation in Finland. The interviewees' own interpretations were solicited; hindering and advancing elements, for example, were not predefined by the interviewers. There were also other questions, but in the current study, these were handled only if the interviewees mentioned something about the abovementioned topics. The interviews lasted about one to one and a half hours and were audio-recorded and transcribed. An interview guide with questions and general instructions was prepared for the three authors who conducted the interviews. The interviews were conducted in Finnish, and the quotations were translated to English.

Data analysis

A thematic analysis was carried out to transform the collected data into themes and provide a basis for answering the research questions. A thematic analysis was chosen as an analysis method because it is a useful method for examining the perspectives of different stakeholders, highlighting similarities and differences and generating unanticipated insights (Nowell et al., 2017). The analysis followed the framework documented by Braun and Clarke (2006): familiarising with data, transcription, generating codes, searching for themes, reviewing themes, defining and naming themes, and producing the report. The Atlas.ti software was used to assist with the phases of generating initial codes and searching for themes. In the present study, after careful reading the transcribed interviews, the content was first coded under the main themes: structural holes, knowledge needs, brokerage functions and the roles of brokers. The themes of brokerage functions and the roles of brokers were further divided into subthemes (national, regional and organisational). Each subtheme was then analysed according to which roles were highlighted and what information needs were associated with brokering at these levels. Next, a comparison between the themes was performed to figure out the macro-, meso- and micro-level brokerage needs, tasks and roles in care robotics innovation ecosystems and what kind of knowledge should be brokered on these different levels. At the end of the analysis, the results were compared with prior research related to knowledge brokerage and care robotics innovation ecosystems or networks. To establish trustworthiness in various phases of the thematic analysis, researcher triangulation was used (Nowell et al., 2017), meaning that after the first author had analysed the data, the other authors (who had conducted the interviews) read through the analysis and made comments and clarifications.

Results and Discussion

Overview: The need for brokerage in building care robotics innovation ecosystems and networks

An overview is first presented of the need for brokerage in building care robotics innovation ecosystems and networks. Networking includes all the activities used to acquire and maintain connections with external sources, including individuals and organisations; comprises both formal and collaborative projects and more general and informal networking activities (van de Vrande et al., 2009; Chesbrough et al., 2006). According to the interviews, networking was considered one of the most important factors in developing care robotics and in their adaptation in social and health care, but networking was not really happening at the time of the interview. The networking was described as '*insufficient*' and '*coincidental*', indicating that actors were missing or that they were not systematically involved in development activities. It was acknowledged that there were some care robotics networks, but these were mostly local or regional, as explained by one interviewee (meso: organiser of public services): '*We do have many networks here in our region and in metropolitan area, but they do not necessarily reach out to provinces, so there could be other actors somewhere in the provinces, and you are not naturally in contact with them*'.

The networking perspective on innovation emphasises the importance of exploring and exploiting weak ties (Granovetter, 1973) and structural holes (Burt, 2004). In the current study, structural holes were found between organisations. The interviewees, for example, considered that there were not enough connections between care robotics service providers and user organisations. Also, it was considered that robotics service providers and universities should more closely cooperate to develop services. In the field of robotics, there is space for new business activities, professions and educational programs, and improvements should be made in cooperation between robotics service providers and universities.

In addition, there were structural holes between professions. One interviewee (meso: company) familiar with the social and healthcare sector pondered the following: *'…do the engineers really recognise the problems in our social and health care sector so that they are able to develop solutions to these particular problems?'.* This indicates that it is difficult to develop robotics based on only one type of expertise. Complementary expertise and know-how were mentioned as one of the benefits of networking. However, developing innovations requires heterogeneous knowledge bases. Interactions between heterogeneous knowledge bases in an organisation and with external knowledge bases is necessary to experience diversity, but the presence of relevant knowledge does not imply that the inflow of new ideas into the organisation is an automatic or easy process. For example, one interviewee (meso: interest organisation of professionals) stated, *'… we have also tried to organise networking events here, but people are so busy that they don't have a full day to give so that it would be possible to get, for example, our members of parliament to the same event and take these things forward'.* This indicates the need and space for brokerage functions.

Macro-level brokerage

The need for a national brokerage organisation

Moving on to macro-level knowledge brokerage, the need for a national brokerage organisation was brought up. According to the interviewees, a skilled, national brokerage organisation was needed but was lacking at the moment. There have been some attempts at this, though. Some interviewees mentioned the Well-being and Health Sector Artificial Intelligence and Robotics Programme, which supports and speeds up the utilisation of artificial intelligence and robotics in Finland. They commented that it has done good work in organising seminars and bringing different stakeholders together, opening up, for example, the conversation about ethical issues related to robots in its seminars. However, some more concrete actions were seen as being needed at the national level. One interviewee (macro: funding) described expectations towards the brokerage functions at the national level as follows: *'…some centralised agency that would compile our competences and contact information and projects—that would probably be good, and that it would be international, English-language, so that it would also serve these international collaboration networks'.*

In some interviews, the interviewees were not discussing only networks, but they stressed that there was a need to build an ecosystem, as one interviewee (macro: political decision maker) explained: '*If we would have a core organisation that is responsible, and it has permanent activities, where different actors are paired up. Something like in many clusters, but they do it wrongly because they have only competitors together. It is not cooperation because they compete; we should find those actors that have synergy*'. This implies that at the national level, knowledge brokerage focuses on the structure of the network by building steering mechanisms and creating operational preconditions in general. This function resembles the role of broker as a policy executor, whose tasks are acquiring new network actors, investing in the long-term development of relations and building an innovation environment that consists of various actors and networks (Parjanen, Melkas & Uotila, 2011).

There were several roles that a national broker could have. As a coordinator (Gould & Fernandez, 1989), the national broker favours the exchange of information and knowledge between the actors in the care robotics innovation ecosystem. This would enhance communication between different actors and strengthen the links within the network by increasing the connectivity between the actors. At this stage, the broker creates possibilities for partners to find each other. Along with the abovementioned roles, national-level brokerage can play a gatekeeper role (Gould & Fernandez, 1989) when considering international connections. Going further than brokering nationally, this national broker role is to act as a gatekeeper connecting local activities and international best practices and research. This role could include a transfer of practices and the drawing of analogies between Finnish social and health care and foreign care systems, as one of the interviewees (macro: insurance) explained: *'How much are development or experiences followed from outside of Finland… It is the same, anyway, older people probably have the same needs everywhere, so it would seem to me to be quite a good driver if, for example, something has been developed in Germany or perhaps in Asia, where they are much more advanced in these issues, I've heard—that the lessons learned would be taken'.*

One of the brokerage functions at the national level is to maintain public discussion about the use of robotics in care. Some interviewees noted that visibility was especially important in implementing robotics. One important group with whom to share knowledge about robotics in care was decision-makers. According to one interviewee, it was important that people know what kinds of research and development projects there have been, what the results are and what the possibilities are for robotics in care. It was considered that a national broker could have more possibilities to contact media and act in a representative role (Gould & Fernandez, 1989) of the care robotics ecosystem or network than an individual actor.

One of the hindrances to the development and implementation of care robotics was found in the current funding system. It was acknowledged that the many funding opportunities were difficult to use, and special expertise was needed to apply for the funding. Thus, an important part of the knowledge brokerage at the national level was the identification of funding sources and the brokering of that knowledge to the regional level. The interviewees commonly stated that there was a need for brokers who could use their experience to locate various funding opportunities (EU, national, regional, etc.), inform about them and develop new methods and practices for how the ecosystem or network actors can use them more efficiently.

Brokerage organisations at the national level

In addition to national-level brokerage, the interviewees recognised several organisations that already act as brokers at the national level, such as universities, individual departments of universities or various trade or expert organisations. These organisations play a broker role as a by-product of their other activities, not as a main activity (see also Howells, 2006). Some of the interviewees of these organisations noticed that their work contained brokerage functions, such as matchmaking, exchanging experiences, information and knowledge sharing and motivating actors to conduct various pilots. One of the interviewees (meso: interest organisation of end users) explained that the organisation also had a good possibility to act as a broker: '*We have a good coupling right now to the field that does direct client work, so that we would be able to unite these actors'.* These organisations acted at multiple levels, having links to the employees and managers in the social and healthcare sector but also to decision makers such as members of parliament. This implies that their role resembles that of a representative (Gould & Fernandez, 1989): they diffused knowledge, for example, from the employees of the social and healthcare sectors or clients of the care homes to the decision-making levels.

The intermediary organisations that would play a brokerage function as their primary role, such as the Finnish Innovation Fund Sitra and Business Finland, were also mentioned. The role of these organisations was found to be close to the view of van Lente et al. (2003) of an intermediary working as an independent facilitator of innovation activities in organisations, networks or a region. Neutrality as an actor and trustful knowledge were related to these organisations. It was considered important that these kinds of broker organisations pilot technologies and show how technologies work in practice and produce information for future activities. Actually, Hargadon and Sutton (1997) stressed the proactive role of brokers in technology and innovation transfer. Their duty is not only to scan and acquire knowledge, but also to store it to make it usable by different users. This activity also resonates with the role of brokers as sniffers of future knowledge (Parjanen, Melkas & Uotila, 2011).

The role of universities in care robotics ecosystems or networks was mostly related to generating scientific knowledge. The needed knowledge was multidisciplinary, including, for example, technological and social aspects. According to the interviewees, scientific knowledge was available, but the challenge was that it was mostly in English and difficult to use in practice. The failure to use scientific knowledge may hinder the development and implementation of care robots, implying that there is a need for brokerage functions that include finding, assessing and interpreting research into practice.

Meso-level brokerage: Educational organisations as regional brokers

At the regional level, the universities of applied sciences were considered to have an essential brokerage role, especially in supporting local companies: '*But mainly that there could be an educational organisation to support some local company's operations. Because then the networks would be much, much broader right away'* (meso: company). The functions that the universities of applied sciences were responsible for as brokers are related to network formation and innovation process management. In these activities, a university of applied sciences would play the liaison role (Gould & Fernandez, 1989). At the regional level, the broker intermediates between organisations at different stages of the value chain, with each of them having a distinct knowledge and information base. The broker needs to identify suitable partners for the project in question, bringing them together for preliminary discussions in view of a possible collaboration. After that, the brokers play a coordinator role (Gould & Fernandez, 1989), keeping the network together by taking care of day-to-day network management issues, enhancing trust and resolving conflict (see also Kingsley & Malecki, 2004).

It was considered essential that working life would be more effectively involved in developing and implementing care robotics. This would happen if the universities of applied sciences could build various innovation, test and development laboratories. In these laboratories, the companies would have the possibility to develop their products and services with various stakeholders, and the user organisations would have the ability to get familiar with these products. In this sense, the broker would act as a creative actor making possible and developing the necessary creativity and new type of thinking needed in the innovation process and as a crosser of distances enabling the cross-fertilisation of knowledge (Parjanen, Melkas & Uotila, 2011). To share knowledge and experiences about care robotics, several interviewees suggested that the social and health care students would be a valuable resource of brokerage functions, and they would especially have an essential role in assisting the adoption of robotics

One of the essential brokerage functions at the regional level was collecting user knowledge to enhance product or service development: *the more users could be involved in the planning, surely the better… the implementation would be smoother'* (meso: company). In this context, user knowledge was related to the knowledge that the employees in the social and healthcare sector hold about the challenges and possibilities of the use of care robotics, but also the experiences of the client about the use of care robotics in everyday life. According to the interviewees, it would be essential for user knowledge to be collected by a neutral actor to better reveal the impacts of care robots.

Micro-level brokerage: Intraorganisational level

In the interviews, the need for internal brokerage functions was emphasised (Wenger, 1998; Cillo, 2005; Parjanen & Hyypiä 2018). The need was highlighted, especially when implementing care robotics. After the company presentations, there should be a peer who knows how to use the robots and is eager to guide others in their use. This kind of training should be long term and should consider the characteristics of the social and healthcare sector. The internal broker was considered to be a peer, as one interviewee explained: '*Maybe it's the peer aid, peer support, peer information on every level…'* (micro: managers). The purpose would be to share experiences about care robotics, hence reducing the possible distrust and timidity among users. The social proximity between the internal broker and employees and knowledge about the organisation's practices were deemed as essential to internal brokerage (Parjanen & Hyypiä 2018) because the hands-on approach was considered the most suitable for internal brokerage. In addition, brokered knowledge could often be tacit knowledge: '*We don't need so much technical knowledge but knowledge about using it (the robot)*' (micro: managers).

These internal brokerage functions include mentoring and encouraging employees to use care robotics and discussing the practices of using them. One of the interviewees (meso: interest organisation of professionals) described this as follows: '*According to my view, it is a very good practice that you have regular discussions with more experienced employees and you have the possibility to learn, get information and skills*'. Thus, internal brokerage can create the possibilities for learning by promoting open communication about the role of care robotics and knowledge sharing about the best practices of using care robotics, thus playing a coordinator role (Gould & Fernandez, 1989). An important task for brokers was to collect information from users for development purposes. This was seen as essential because knowledge '*from users and consumers to designers is incredibly important, since there are often things that have to (be taken into account)… so that information also flows backwards in terms of whether it works or doesn't, or that this or this desired (function) is missing'* (micro: managers).

One part of internal brokerage functions is to lessen the in-house hindrance and resistance to innovation and new practices, including robots. The interviewees described that many employees were still quite suspicious and afraid of the future, and it could be good to have some kind of '*attitude training*' so that employees could gradually be ready for new practices. An important part of this training would be to establish a trustworthy atmosphere to allow the necessary flow of information to take place, but also to help employees to overcome their reluctance to take part in development and implementation processes. This role resonates with the broker as a shaper of organisations (Parjanen, Melkas, & Uotila, 2011).

Conclusions

Multilevel roles and functions of brokerage and brokered knowledge

This study identified the brokerage functions in the context of the care robotics innovation ecosystem. As shown in Table 1, some of the functions are similar to those found in earlier studies conducted in different contexts, but there are also functions that are specific to this emerging type of technology and the various questions and concerns around it, requiring, for example, broad public discussion to increase general understanding about the strengths, weaknesses, opportunities and threats of care robotics use, as well as to tackle prejudice and promote informed choices (see also Tuisku et al., 2019; Melkas et al., 2020).

Brokered knowledge should be of diverse types. At the macro-level, knowledge needs are related to the overall functions of the innovation ecosystem. In the short term, the actors of the innovation ecosystem need system-level knowledge about the steering mechanism, operational mechanism and funding opportunities of the emerging care robotics innovation ecosystem. State-of-the-art knowledge is related to knowledge about actors or potential actors of the innovation ecosystem and their role in the development of robotics. The need for international knowledge—both scientific knowledge and knowledge about best practices—was acknowledged. Openness to international knowledge was considered an enabler of innovation at different levels of the ecosystem.

In the long-term, future-oriented knowledge is needed to identify future business potential and combine different resource bases to secure the functioning of the innovation ecosystem. It should be noted that brokers need to be able to both explore future-oriented knowledge and exploit it in practical innovation processes at the meso level of the innovation ecosystem.

At the meso level, the knowledge needs are related to network formation, such as knowledge about potential innovation process partners and their expertise, and innovation process management, such as knowledge about the innovation processes (e.g., scientific vs. practice-based innovation processes) and innovation types (e.g., product/service, radical/incremental). In addition, knowledge needs are related to how to facilitate the creation of cross-sectoral and multidisciplinary knowledge by building various innovation arenas and using different innovation methods. In this study, it was acknowledged that innovations in the care robotics innovation ecosystem could not be based only on one type of expertise; instead, a diversity of knowledge would be needed.

At the micro level, the role of experimental and tacit knowledge was highlighted by the interviewees. The role is especially central during the implementation phase. The knowledge needs are not related to the technological aspects of the care robots but to how to use them and in the customers' best interests. The user knowledge was highlighted in the results; this indicates that users are important sources of innovation. It also indicates that users, in this case, for example, senior citizens, are special members of the innovation ecosystem, as pointed out by Camarinha-Matos et al. (2015) in their study. While collecting user knowledge and the impacts of the use of care robotics, the neutrality of the brokers was considered important.

Table 1. Multilevel roles and functions of knowledge brokerage and types of brokered knowledge

Levels	**Roles**	**Functions**	**Brokered knowledge**
Macro	Policy executor*	Creating steering mechanism and operational conditions	System-level knowledge
	Coordinator**	Enhancing communication and increasing connectivity in the network Matchmaking	State-of-the-art knowledge Scientific knowledge
	Gatekeeper**	Connecting local activities and international best practices and research	International knowledge
	Representative**	Maintain public discussion Knowledge sharing with media and political decision-makers	Knowledge about the research and development projects, their results and impacts
	Sniffer of the future*	Piloting technologies Producing information for future activities	Future-oriented knowledge
Meso	Liaison**	Network formation (scanning, filtering and matchmaking of various sources of knowledge)	Knowledge that different organisations have
	Coordinator**	Network management and innovation process management Trust building	Knowledge related to day-to-day network/innovation process management issues
	Creative actor*	Stimulating new types of thinking needed in the innovation process	Cross-sectoral and multidisciplinary knowledge
	Crosser of distances*	Building various innovation, test and development laboratories to cross-fertilise knowledge	Cross-sectoral and multidisciplinary knowledge User knowledge

		Helping to combine the knowledge of two or more partners Collecting user knowledge	Knowledge about the impacts of the use of robotics
Micro	Coordinator**	Sparring and mentoring employees Organising learning opportunities Collecting user (employees, clients) knowledge	Experimental knowledge Tacit knowledge User knowledge
	Shaper of the organisations*	Lessen the in-house resistance to innovation and new practices	User knowledge
Notes: * Parjanen et al., 2011 ** Gould & Fernandez, 1989			

Concluding remarks

To increase the understanding about knowledge brokerage in emerging innovation ecosystems and networks, the current study has examined brokerage needs, roles and functions in the context of the care robotics innovation ecosystem in Finland. The Finnish care robotics innovation ecosystem is in its birth stage, meaning that networking between different actors is not yet taking place, at least to a sufficient degree, and that essential actors may be missing or are not systematically involved. Complementary expertise and know-how are missing, indicating that there are several structural holes, for example, between care robot service providers and user organisations and between engineers and social and healthcare workers, which can hinder collaboration.

To bridge these structural holes, the need for knowledge brokerage was clearly identified. On the one hand, there is a need for a national brokerage organisation, and on the other hand, there was the need for internal brokers inside social and health care organisations. In an emerging innovation ecosystem, the functions and roles of brokers are versatile and differ across levels. On the other hand, one broker or brokering organisation typically has several roles. The needs for knowledge differ—the brokered knowledge is of diverse types (future-oriented knowledge, scientific knowledge, practice-based knowledge, tacit knowledge, etc.).

For innovation policy practice, this means that there is a need to foster brokerage functions in the emerging innovation ecosystem. The policy objective at the national and regional levels is to exploit the potential of the structural holes of different networks with the help of knowledge brokerage. In planning brokerage training, it should be taken into consideration that brokers cannot be considered a uniform group with similar roles and functions. Instead, there is a need to plan the training according to the characteristics of brokerage at different levels.

As a limitation, the current study has focused on brokerage needs in the Finnish care robotics innovation ecosystem. Hence, there might be some country-specific characteristics affecting the results. In addition, because of the context-specific nature of the care robotics innovation ecosystem, it may not be appropriate to generalise the research results without taking the differences in the fields of activity into consideration. Avenues for future research could include what kind of innovations may emerge at the different levels via brokerage (radical and systemic innovations at the national level and employee-driven innovations within organisations). Future research could also focus on how roles and functions possibly change as ecosystems develop; this may, for example, include how brokers at different levels cooperate to facilitate information flows and encourage innovation in the ecosystem.

Acknowledgements

This study was supported by the Academy of Finland, the Strategic Research Council (Project name: 'Robots and the Future of Welfare Services' – ROSE; decision numbers: 292980 and 314180). The authors also wish to thank all the respondents as well as the anonymous reviewers for their comments that helped improve this paper.

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