Drivers, Barriers and long-term Requirements of assistive Technologies supporting older Persons in living longer independently at Home: A systematic Review of European, US-American and Japanese Policy Papers and Assessment Studies

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Abstract

Countries around the world are facing an acceleration of population ageing. This demographic change has primarily impact on our ways of supporting the older population in its efforts to age well and independently at home while reducing the burden of caretakers and controlling health care costs. One major innovation field are assistive technologies. Nationwide policies, strategy plans and research activities have all shaped current and future trends of these technologies. Not surprisingly, various types of assessment studies were carried out to investigate when, how and under which conditions it is advisable to utilise assistive technologies. This review of pertinent literature from the USA, Europe and Japan is the first of its kind. All reviewed policy papers and studies see the technological advancement of assistive devices as a prerequisite for dealing with an aged population but postulate different approaches and long-term goals This paper analyses the demographic, social, ethical, economic, medical and technological aspects of assistive robotic technologies addressed in the papers and interprets the results in an international, comparative perspective. Technological, legal and political barriers play major roles and ethical as well as societal issues are widely reflected. On the other hand various economic, societal and technological driving forces are discussed. Although the described barriers are intensively taken into consideration, the focus on driving forces seems to suggest that the use of assistive technologies for supporting older persons to live longer independently at home will be feasible in the very near future.

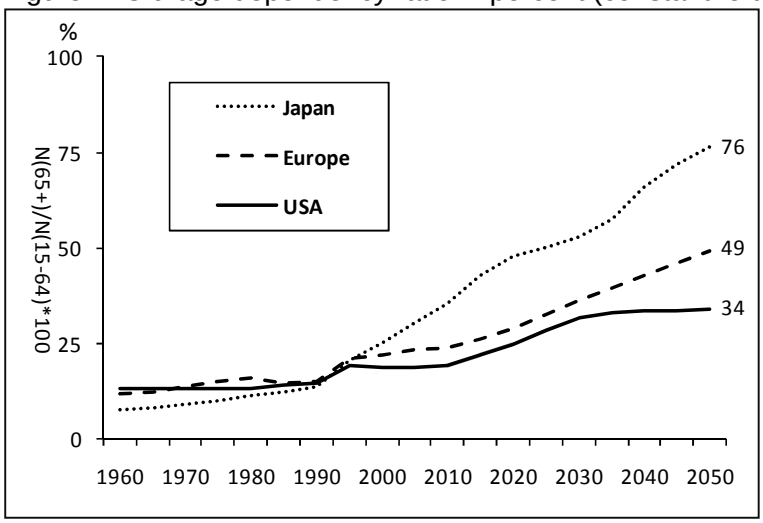
Keywords

ageing, assistive technology, future, care, support, older population

Introduction

Taking care of their older populations is one of the major challenges currently faced by ageing societies.[1] As the demographic change accelerates, this has become an increasingly relevant issue.[2] Scientists and experts have proposed various ways of solving this problem. Technological progress nowadays permits older persons to live independently with the help of assistive robotic devices.[3] Support ranges from telecare/smart homes, proactive service systems and household robots to robot-assisted therapy/social assistive robots.[5] Surveillance systems can detect when a person falls down, test the blood pressure, recognise severe breathing or heart problems and immediately warn a caregiver.[1] Interactive robots co-operate with people through bi-directional communication and provide personal assistance with everyday activities such as reminding older persons to take their medication, help them prepare food, eat and wash.[4] These technological devices collaborate with nursing staff and family members to form a life support network for older persons by offering emotional and physical relief.[6] Figure 1 shows the impact of population ageing as a major driver for investing into the development of robotic assistive technologies.

Figure 1: Old-age dependency ratio in percent (constant fertility scenario)



Source: United Nations (http://data.un.org; own figure)

The impact of demographic population ageing is depicted by the old-age dependency ratios for Japan, Europe and the USA. Assuming a constant fertility scenario, the United Nations used this indicator to project the population development. The percentage of the 'dependent population' is calculated as the number of all those aged 65+ divided by the number of all those aged 15 to 64. This is a crude indicator with some shortcomings. Advancements in medical care and other fields of society may change the old-age dependency ratio, because older people will stay healthier until higher ages than they do nowadays.[7]

Japan is deemed to be the first country where population ageing will become relevant in the near future (its old-age dependency ratio is estimated to reach 76% by 2050). To cope with this situation, the Japanese government wants to introduce a nationwide system of robotic assistive technologies for aged care and heavily invests into the development of so-called service and health-care robots. This is documented by research agendas, roadmaps and visions of Japanese institutions and ministries. In Europe, investments into assistive devices (financed within the scope of the 7th EU framework programme) strengthen their development. These expenses are justified by an estimated old-age dependency ratio of 49% by 2050. Although the situation is less dramatic in the USA (old-age dependency ratio of 34% by 2050), the US government subsidises the

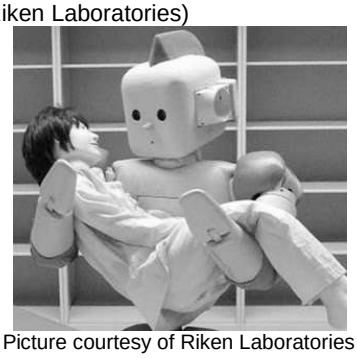
development of robotic assistive technologies, whose innovative potential is reckoned to be comparable to that of the internet and modern media.[8]

This paper presents the results of an analysis of roadmaps, policy papers, technology assessments and forecasts of the future of assistive robotic technologies in aged care. It shows how governments across the world see robotic assistive technologies as a possibility of supporting older people and outlines the conditions for their development and implementation based on an analysis of drivers, barriers and future requirements. This first review of pertinent international literature comprises Japanese, US-American and European studies. It offers a synopsis of worldwide developments and perspectives of robotic assistive technologies. The reviewed literature prepared by a wide range of political initiatives, organisations and research institutes is very heterogeneous. Many papers consider only some important aspects or use different approaches to elaborate what a future with robotic assistive technologies might look like. The aim of this article is to present an overview of available studies, their different approaches and methods. The results will give researchers, policy makers, technicians, companies and other stakeholders a comprehensive and comparative overview of current and future developments in this field.

Robotic assistive technologies

The term 'robotic assistive technologies' comprises all autonomous or semiautonomous robots that support humans in their daily activities and help them live independently in their homes. The development of personal robots is expected to increase over the next decades while manufacturing costs are expected to decrease. It is even predicted that the production of personal robots will surpass that of cars in 20 years.[9] Although personal robots are very complex, the production of robots that are capable of supporting persons has made significant progress. Different types of robots were developed to meet specific needs of the older population. The following figures (2-4) show three examples of robotic assistive technologies that already exist and are considered suitable for mass production.

Illustration 1: Lifting robot *RiMan* (Riken Laboratories)



Picture courtesy of Riken Laboratories

Illustration 2: Meal assistance robot *My Spoon* (Secom)

Picture courtesy of www.boston.com

Illustration 3: Home-assistance *Care-o-bot 3* (Fraunhofer IPA)

Picture courtesy of Fraunhofer IPA

Lifting robot *RiMan* was developed in Japan and is a good example of how robots can help caregivers with lifting older persons, for example, from their bed or other places in their home. Although the lifting process was tested extensively to meet safety requirements, *RiMan* supports caregivers in their daily work rather than replacing them. It is a major step forward in easing the physical burden of caregivers and preventing health problems that may result from lifting heavy persons.

The meal assistance robot *My Spoon* was developed by Secom in Japan to help older disabled people eat their meals. The photo shows Japan's Health Minister Yoichi Masuzoe at a test meal. This type of support helps elderly people regain their independence because they do not need to

be fed by caregivers. They can control this semi-autonomous robot with a joystick attached to their jaw, hands or feet. This assistive robotic device is already on the market.

Care-O-bot 3 is a home-assistance robot developed by research scientists at the Fraunhofer Institute in Germany. Being the third generation of its kind, it assists humans with their household chores. Although the robot can only perform such basic tasks as picking up bottles, cups or similar objects, its highly flexible arm has proved to be safe when operating near humans.

These three examples of robotic assistive technologies demonstrate the different supportive tasks specific types of robots can perform. Despite the high demand for this kind of assistance, the barriers and limitations are evident.

Review methodology

The aim of this literature review was to find out how roadmap studies, policy papers, technology assessment studies and forecasts portray our future with regard to robotic assistive technologies. The studies were identified with the help of electronic journal databases (Scirus, Scopus, IEEE Xplore, J-STAGE, Namazu) and internet searches with the following keywords: 'robotic assistive technologies' AND 'aged'; 'care'; 'old'; 'elderly' AND 'roadmap'; 'forecast', 'policy'; 'technology assessment'. To identify Japanese papers translated key words were used for searching the Japanese databases. The review includes works on current and future trends of robotic assistive technologies in health care, and specifically aged care. The focus was on worldwide future studies and, in particular, on European, US-American and Japanese studies. The first search run yielded 112 studies that deal with future aspects. However, as we were mainly interested in studies that also address the driving forces, barriers and long-term requirements of robotic assistive technologies, we reduced the sample to 38 studies that contained the required information. All of these studies were analysed in their original languages. All papers were published between 2001 and 2011. The sample comprises 18 roadmaps and policy papers, ten technology assessment studies and ten studies classified as forecasts. Based on different approaches, all papers predict a future where assistive technologies support humans with various kinds of needs.

Typology of the literature about the future of robotic assistive technologies

Roadmaps and policy papers

Roadmaps are normative and present a desirable future with robotic assistive technologies. They start with visions and end with step-by-step instructions of how to implement them. Assumptions about the future are neither made explicit nor described in detailed storylines. Instead, the future is interpreted by means of actions to be taken and targets to be met.[10] The main task of roadmaps is to make policy recommendations. They are often drawn up after expert workshops and meetings with various key stakeholders who develop a shared vision of the future of robotic assistive technologies by considering current possibilities, future prospects and potential barriers. The result is a holistic view of the future, a pathway of actions that need to be taken in order to reach the proposed targets. Policy recommendations are usually made for the short term (5-10 years), while policy goals are set for longer periods (up to 2050 and beyond).

Policy papers often refer to roadmap studies. Most of them are based on governmental initiatives. Their aim is to provide more detailed suggestions for the implementation of robotic assistive technologies. They also address challenges, barriers and requirements and specify which decisions on the political, scientific, economic, technological and ethical levels have to be taken to reach the desired goals. Often the costs of publicly funded care in an ageing society are mapped against the investments into robotic technologies that ease the burden on the care system by demonstrating how the latter will benefit from assistive technologies. Cost-benefit analyses are

rare in policy papers and roadmap studies because it is difficult to estimate how assistive robotics will develop on the mass market.
The following table provides an overview of the reviewed roadmaps and policy papers, along with a brief description and the countries they relate to (robotic assistive technologies = RATs).

Table 1: Roadmaps and policy papers

Ref.	Brief description	Region
11	The paper identifies social drivers, potentials, key challenges and deployment issues related to RATs.	USA
12	This roadmap was developed after an expert workshop. It outlines what is needed to facilitate the provision of suitable RATs and addresses key challenges for their implementation.	United Kingdom
13	The report offers a holistic view by describing the most important conditions for living independently, the electronic support required to fulfil them and the challenges posed by the implementation of RATs.	Europe (EU)
14	The study investigates the potential of robotics and presents key policy recommendations for the application of RATs in healthcare.	Europe (EU)
15	This report draws upon the results of work in the region around Osaka, where companies, research institutes and organisations make collaborative efforts to promote and develop RATs.	Japan
16	The report outlines major innovations to be introduced by Japan until 2025. Unlike other roadmap studies, it focuses on visions of a future in which robots and humans coexist.	Japan
17	The paper addresses the potentials of RATs by focusing on key business drivers, barriers that have to be overcome and technological challenges.	Worldwide
18	The report analyses the current stage and future development of RATs in Europe and singles out the issues that ought to be developed and strengthened in Europe.	Europe
19	Based on the history of research and development in technologies, this roadmap outlines how and when robotic technologies become feasible.	Japan
20	This policy paper summarises the economic, social, political and technological issues that have to be considered for a successful implementation of RATs in a world characterised by demographic change.	Japan
21	The policy study describes the prerequisites for RATs while concentrating on social issues, current implementation strategies and future possibilities.	Japan
22	The report summarises existing research and describes the possible future of RATs. It also presents various RATs which are already on the market or in a developmental stage.	Japan
23	The report deals with various aspects of aged care (insurance issues, quality of care, improving nursing care facilities etc.) and describes how RATs could be integrated into care.	Japan
24	The study presents driving forces of and obstacles to RATs with a focus on existing research and development.	Japan
25	Based on the success of industrial robots, this study summarises previous efforts made in the field of RATs and proposes measures and developments for their effective implementation.	Japan
26	The paper outlines major findings of workshops with various experts who discussed the future impact of RATs.	USA
27	The paper presents the results of a roadmap study and shows ethical barriers with regard to the development of the next generation of humanoid robots.	Europe (EU)
28	The study presents influential factors for the development of RATs and shows their current and future potentials.	Netherlands

Table 1 clearly shows that roadmaps and policy papers are mostly commissioned by nationwide and supranational institutions. The goal is to formulate and implement strategies to put them in the lead in this new field. Especially the Japanese roadmaps and policy papers emphasise the future role of Japan as a leading country in robotics. The following Japanese ministries were involved in the preparation of the policy papers listed above: Ministry of Economy, Trade and Industry, Ministry of Health, Labour and Welfare and institutions receiving governmental support such as the New Energy and Industrial Technology Development Organization, the Innovation 25 Strategy Council and the Kansai Promotion Council. In Europe, initiatives funded by the European Union have produced a number of roadmaps and policy papers by various strategic alliances, among

them the European Robotics Platform, the European Ambient Assisted Living Innovation Alliance, the EURON Roboethics Atelier (European Robotics Research Network) and the Directorate General Information Society and Media of the European Commission. Other studies were commissioned by countries such as the USA (Computing Community Consortium), the United Kingdom and the Netherlands. The study of the European Robotics Platform considers developments across the whole world.

Technology assessment studies

Technology assessment was introduced to assist public policy decision-making[10]. Its primary goal is to inform policy makers about the potential political, social, ethical, economic and other consequences of an emerging technology by focussing on unanticipated and unplanned effects. Nowadays technologies are assessed by public or governmental organisations, institutions and independent researchers. The following table summarises the reviewed technology assessment studies prepared by scientific institutions and researchers.

Table 2: Technology assessment studies

Ref.	Brief description	Region
29	The paper presents the key aspects of a future 'robotic society' by summarising in-depth interviews with experts and participants who interacted with a humanoid robot for the first time.	Europe
30	Based on rather detailed visions of future robotics, the paper outlines less speculative ethics of technology.	Netherlands
31	The paper deals with the technological, ethical, economic and legal aspects of using robots that may fully or partly replace activities of humans.	Germany
32	The paper evaluates ethical issues of RATs in aged care with a focus on the quality of care and social attitudes towards older persons.	Australia, worldwide
33	The study outlines the requirements, challenges and possibilities of future assistive technologies.	USA
34	The paper describes emerging silver industries that offer new business opportunities.	Japan
35	The paper presents three technology options for aged care in Japan and their impacts for various target groups.	Japan
36	The study outlines various problems posed by the rehabilitation of the older population and their implications for legislation and public care insurance.	Japan
37	This article focuses on social robots, visions of RATs and the importance of cultural factors for attitudes towards them.	Japan
38	The paper presents an international assessment of industrial, personal and service robots by analysing the market situation and trends, the state of the art in theory and practice and future challenges.	US, Europe, Japan, Korea, Australia

All these research papers assess the impact of robotic assistive technologies on society. Emphasising the current and future needs of an ageing population, they take into account various aspects to outline a future where robotic technologies support caregivers or even partly or fully replace activities of humans. All of these studies assume that robotic assistive technologies will play a major role in aged care. The only exception is the study by Sparrow and Sparrow,[32] which states that robots may negatively affect the quality of care or social attitudes towards older persons. Other studies outline the great opportunities for newly emerging industries and markets by arguing that aged customers are an important target group with huge buying power whose needs can be met by offering sophisticated assistive devices.[34,35,38]

Forecasts

Forecasts are descriptive works that use quantitative methods to predict the future based on current trends or on surveys of expert opinions.[10] Most of them study the current market for robotic assistive technologies and predict how it will develop in various scenarios, e.g. with strong

governmental funding, policy interventions or rapid developments of new technological components. The forecasts often have a rather deterministic view of the future. They concentrate on new technologies that substitute old ones and do not pay special attention to current technological paradigms.[10]

Table 3: Forecasts

Ref.	Brief description	Region
39	The forecast presents the results of a collaborative research project run by NISTEP and Tekes that elaborated solutions for an ageing society.	Japan, Finland
40	The paper deals with the future development of personal service robots based on results of a forecast study.	Europe, Korea
41	The paper analyses the social context for new RATs and the impact of technological innovation on the economy and society.	Spain, Japan, EU
42	The forecast presents an overview of the older population and people with disabilities and examines how governmental programmes and laws may make RATs meet their needs.	Japan
43	The paper reviews global trends and future perspectives of RATs by means of current applications.	Korea, Japan, USA
44	The paper describes differences and similarities of selected technology forecast studies.	USA, Japan, UK, Netherlands
45	The article reflects on the perspectives and possibilities of RATs for aged care.	Austria
46	The paper provides an overview of worldwide producers and developers of RATs. The focus is on different types of robots, level of distribution and cost/benefit analyses.	Worldwide
47	The report deals with recent and future technological and economic trends of intelligent robots.	Worldwide

Table 3 shows that nearly all forecasts describe the technological development in more than one country. Many of them focus on international cooperation and its positive outcomes.[39] Another aim is to compare global producers and developers of robotic assistive technologies to gain more insight into the market situation, target groups, distribution levels and costs versus benefits.[40,43] Some of the presented forecasts compare countries from collaborative viewpoint, while others concentrate on competitive aspects.[42]

Drivers, barriers and long-term requirements for robotic assistive technologies

The development and implementation of robotic assistive technologies are multifaceted. The process is mainly driven by demographic ageing and triggered by governmental support (push factor). The review showed that economic, technological, medical, social, ethical, legal and political aspects are important drivers, but may also inhibit robotic assistive technologies. The next subsections analyse how the different aspects hinder or intensify the development and implementation of RATs.

Demographic, social and ethical aspects

Almost all studies justify the development of robotic assistive devices by the accelerated population ageing and its negative consequences for employment, health-care and pension systems. Not surprisingly, many of the papers start with an introduction to the demographic change. Robotic assistive technologies are not presented as a process counteracting this change but rather as a measure that mitigates its consequences. On the one hand, demographic ageing increases the old-age dependency ratio, on the other hand, it makes the working population shrink. This leads to a growing shortage of staff in formal and informal care services.

Assistive robotic technologies will redefine the work in the care sector. The positive effects of assistive robotic devices that support caregivers and older persons are assumed to increase the quality of care. However, one major prerequisite is that robotic assistive technologies should not

replace them. Robots should do the repetitive and exertive work to give caregivers more time to attend to the social needs of the elderly. According to the studies, the use of robotic assistive devices will raise the image of care work. However, this not only requires an effective, lifelong technical training of caregivers but would also entail significant changes to a mostly entry-level job culture. Thus, it is not only important to develop highly sophisticated technical devices but also to encourage care personnel to integrate these devices into their daily work. In the long run, it will be necessary to also supply training materials showing caregivers how to use them properly.

From the viewpoint of older persons, a major driver for the development of robotic devices is their wish to lead an independent life in their homes even at high ages. Specific types of robots can assist them with their daily chore with little or no help by a caregiver. Autonomous monitoring devices can electronically inform the carer who will only come when the elderly person needs assistance. However, safety is a big issue and the technical feasibility of safe RATs is in its infancy. This issue is discussed in more detail in the section on the technological aspects of robotic assistive technologies. Acceptance issues are also a major concern and may depend on the respective culture. Especially western societies have not yet familiarised themselves with the idea that robots actively help people at home as is the case in Japan where *manga* (cartoons), *anime* (animated cartoons) and the popular culture in general have created a high public awareness of robots.[37] Moreover, the Japanese government heavily subsidises the research on and development of robotic technologies, making it the lead nation in the robotic industry sector. In western societies, science fiction heavily biases the public view of robots as something not yet common in everyday life. However, these cultural differences in perceiving robots do not play a major role in the reviewed papers. The authors mainly argue that robotic assistive technologies have progressed enormously and draw parallels to the development of the internet and modern media. They argue that robotic devices will be more accepted once people become aware of their advantages. The studies also point out that the main concern should be the benefits across the globe. While cultural differences should be taken into account they should not constitute an exclusion criterion. With regard to acceptance issues, in the long run, all stakeholders will have to be involved in the designing and implementation process.

Privacy issues are also a problem. Monitoring devices can store a lot of data that are useful for studying the daily activities and movements of older persons. However, it is not yet clear what will happen with these data. In the long run, access to these data will have to be regulated. Since there will be various robotic devices with versatile monitoring functions, the papers recommend that privacy issues are regulated by a superior authority which informs users about privacy procedures. Another social issue are the costs of robotic assistive devices. It is a major prerequisite that these devices are sold at affordable prices and the financial considerations do not constitute an exclusion criterion.

Medical and technological aspects

Assistive robotic devices can monitor and transmit health-related parameters to medical institutions. Thus, doctors and nurses get an overview of their patients' health status without having to see them every day. As already mentioned in the section on ethical issues above, these records are sensible data. Current data safety standards must therefore be bearing in mind the rapid development of robotic assistive technologies. One solution might be to centralise data storage and put one institution in charge of supervising access.

Since robotic assistive devices will support older persons in their homes, the user friendliness of the interface is a major and well researched issue. As more and more humans will interact with robots, we need to understand how they accept and use them. This may require a long learning phase. Moreover, technicians must be available to help older persons in case of technical/functional problems with the devices.

It is also important that users evaluate prototypes before the robots are produced on a commercial scale. As older persons have very individual needs, it is essential to design robotic devices in such a way that they can be adapted to different requirements. The evaluation should also include the implication of RATs on the individual life of older persons. Robotic assistive devices offer many advantages but are not suitable for every older person. Researcher, designers and developers must bear in mind the individuality of the aged population.

As already mentioned above, safety is both a driver and a barrier. Assistive devices can be installed in the homes of older persons. The technological development of monitoring devices is rather advanced. They can immediately detect such untypical movements as falls and report them to caregivers. However, especially autonomous ubiquitous robotic devices that move around in the house are still in a developmental stage. One of the major technological challenges is to develop components that allow mobile robots to sense and perceive before acting near humans. Besides, robotic devices have different degrees of contact with people and/or different levels of autonomy. Hence, the functions of each robot must be evaluated to establish individual safety standards.

Semi-autonomous or autonomous wheelchairs and robotic suits not only permit older people to lead an independent life at home but also help them to move around outside their homes. As such devices become more widespread, there will be a need to develop risk assessment strategies and appoint certification authorities which also serve as information points. Moreover, mobile robotic devices used outside the home will have to be included in transportation laws to ensure the safety of pedestrians and vehicles. Last but not least, producers will have to ensure that users remain mobile even when the primary power supply of the mobile robot is depleted.

Conducting interdisciplinary research is another long-term prerequisite for the development of robotic assistive technologies. It is essential to understand humans, human-human interaction and human-robot interaction. In order to create intelligent robots, we need to fully understand how the human brain works. To this end, interdisciplinary research in areas such as molecular biology, cognition, physiology, biochemistry – just to name a few – has to be intensified.

Economic aspects

The costs of robotic assistive technologies are a key economic aspect. Most of the research in this area is government funded as the marketing prospects are uncertain. High initial cost might deter potentially interested producers. It could be difficult to break the vicious circle that companies will only produce robots if they can make a profit, but there will be no mass market if assistive devices are expensive. Robotic assistive technologies must be cheap, effective and prioritised over traditional systems. Governments will have to promote their use and ensure that those who need them can afford to buy them. Technological progress will presumably improve the cost-effectiveness of these technologies. However, the value of available devices has to be demonstrated. Reusing components might save costs. Moreover, mass production will also lower costs.

Business options are the main economic driver. Economic success will encourage investments and create new job opportunities. Smaller businesses can make profit by supplying components. However, a co-ordinating body will be needed to ensure that small and large businesses can co-operate. Besides, collaborations across countries are vital. These highly advanced technologies should be developed at a global level and worldwide alliances that exchange results on research and innovations should be strengthened. However, it is also important to keep the industries competitive in order to stimulate innovative projects. This can be done by introducing such award systems as *Robots of the Year* or other incentives. As excessive bureaucracy might slow down

the innovation process, legislative and political decisions should be regularly adapted to ensure unhampered progress.

As already pointed out, economic success will increase job opportunities and lead to the establishment of new educational institutions. It is important to offer adequate and affordable education options, in particular for women, since they play a key role in the care sector. Research and development of robotic technologies need long-term education. To attract young people to this field, robotic technologies should soon be integrated into school curricula.

Political and legal aspects

One major driving force in politics is that widely available assistive devices (at home, in public spaces, mobile assistance) will financially relieve the health-care system. Including them in the existing care provision may be difficult. Policies for licensing, proctoring and teaching will be needed. Reimbursement of costs via insurance companies has to be considered.

Governmental support strengthens the development of robotic assistive technologies. However, political choices with regard to their development and implementation may have far-reaching and not always measurable consequences. Hence, experts and stakeholders must collaborate in formulating standards and laws, and in particular those on liability and responsibility. Who will be held responsible when a robot performs inappropriate or even dangerous actions? In this context, the collaboration and approval of all ministries involved in the decision-making process is a prerequisite.

Another issue in terms of political and legal aspects is how to react to ethical limitations. The protection of users who evaluate the functions and appropriateness of assistive robotic devices may delay the experimentation process. In the long run, this might entail a revision of the legislation on clinical trials.

Discussion

The reviewed studies address future developments. As future events are inherently uncertain, this might be their major weakness. However, projections of the future are not limited to technological developments but capture wider areas of social change. Without forecasts we cannot get ready for the future.[48] Although the increasingly faster pace of change makes it difficult to plan ahead, forecasts can help people, institutions, etc. to take advantage of all the opportunities offered by rapid social and technological progress.[48]

One strategy of roadmaps, technology assessment studies and forecasts is to rely on experts' evaluations of future technologies. Projections of the different dimensions of assistive robotic technologies are based on an assessment of current technological possibilities, while it is difficult to forecast exactly when they will be implemented.

The studies reviewed in this paper were analysed to identify the driving forces, barriers and prerequisites for robotic assistive technologies. Their assessment is based on current structures such as the health-care system. Roadmaps address specific problems and mainly serve as decision-making tools. Policy papers reflect discussions based on roadmaps. Technology assessment studies use current trends to assess future developments. Forecasts project the future with the help of formal quantitative extrapolation and modelling.

The literature review has shown that demographic changes such as population ageing are the main driving force behind assistive technologies. Although the reviewed studies use different research strategies, they all conclude that technological development is among the most difficult

aspects to predict. Many prerequisites such as safe operation near humans, human-robot interaction, building intelligent robots, robots that learn while operating have not yet been fully met, while other aspects, e.g. economic possibilities, are easier to assess. Robotic assistive technologies are a new market segment that will offer many business opportunities and jobs. When they are used to assist older persons, they will also redefine the care sector and upgrade the image of care work. In the long run, assistive technologies will ease the financial burden on the care system and facilitate the work of caregivers. Enabling older people to lead an independent life at home is one of the most important positive aspects. However, it should also be mentioned that many technological hurdles still have to be overcome before robots will become a standard device in older people's homes.

The studies do not specify how a society assisted by robots might change and develop. They emphasise the supporting component but fail to give details about the acceptance of robots in the private and public spheres. They assume that assistive technologies will be promoted and automatically integrated into the health-care system. However, protests from groups which fear that the human component might suffer may impede the large-scale use of robots in aged care. Moreover, the studies underline the advantages of robots and the increasing importance they gain thanks to technological progress and their gradual integration into existing systems. Promotion campaigns for robots will raise the awareness of the possibilities offered by robotic assistive devices, while news about problems (e.g. accidents in the test phase or during regular operation) will lower their image and acceptance.

The studies also fail to comprehensively analyse the effects of such population issues as financial crises, environmental catastrophes or socio-economic developments. The uncertainty inherent in the scenarios we develop also applies to the future of robots in aged care. Moreover, the use of sophisticated technologies requires a high level of understanding. According to studies on the use of the internet, more educated persons have better access to the internet and more knowledge about it than their less educated peers. This 'digital divide'[49] is also an issue with regard to the usage and spread of robotic assistive technologies. The more sophisticated a device the higher will be the impact of educational gaps.

Although the studies do not address the shortcomings in great detail, they present a holistic picture of robotic assistive technologies in a changing world. They thoroughly analyse such aspects as a new promising market and thus constitute an important source of information for all stakeholders. Governmental institutions will benefit from the policy suggestions, research institutions can use the information provided in the studies to allocate resources and obtain governmental funds, economists can assess the pros and cons of investing into these technologies and caregivers and the public at large can inform themselves about future ways of aged care and independent living.

By providing an overview of the literature on the future of robotic assistive technologies, identifying the drivers, barriers and long-term requirements, this paper hopes to provide guidance in this new field of elderly care.

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