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The Development of Assistive Robots for the Elderly

Future Business Opportunities in the European Market

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The growing concern regarding the population ageing has set many to look in to various options that could bring possible relief to some of the problem issues arising. Alongside with the rapid development of assistive robots that has brought promising results to the field, the deployment of these technologies into the daily lives of the elderly has been seen as a possibility to help us in the near future. This research examines what are the different assistive robots that have been developed for the elderly, and how research institutions collaborate for improving these devices to bring them closer to the market. It also looks into what are the current main challenges, especially regarding the ethical issues.

Keywords	Assistive robots, robotics, robotics development

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1 Introduction

Population ageing has become a serious matter of concern leading to new economic and social challenges in many countries. The rapid development of assistive technologies, particularly in the field of assistive robots, has been recognized as a possible solution to this problem which could bring prolonged independency and improve the life quality of the elderly. In addition to that, this sector has been seen as a relative substitute for healthcare workers; a factor that would relieve the growing demand for personnel in this industry, especially for caregivers and nurses in senior homes.

The future outlook for elderly people is a topic that concerns all of us, as there will be a point when someone from our family, a close friend, or simply ourselves, will grow older and could reach a state in which help would be needed for simple daily activities.

Recent studies have demonstrated that due to the demographic changes in the population age structure, there might not be enough people to take care of the elderly in a near future. Based on predictions by 2060, in most of the European countries, the number of people aged 65 will increase by 50 percent and the population of people aged 79 and more will triple. (European Institute of Innovation and Technology 2017: 11). It is also predicted that two thirds of the European population, by the time they would have reached the retirement age, will be likely to suffer of at least two chronic conditions, including dementia or Parkinson's disease. Thus, many will be incapable of remaining independent and probably will require long-term care. Due to that, the spending on long-term care is predicted to increase by 80% (Global Coalition on Aging 2018: 11).

This research examines the current situation of the ageing population in Europe and the state of the development of assistive robots designed to aid them; for the purpose of comparison, some examples are brought from Asia and from America as well. The thesis seeks to analyze the possibility of adapting these technologies in the daily lives of seniors and to find out if this approach would be an effective solution to the growing shortage of personnel on the caregiving industry.

Currently, most of the assistive robot solutions are still in the development stage and they are not commercially available for the end users. These robots are designed to support the elderly and disabled people with different daily tasks, such as eating, bathing, providing companionship or helping with reminders, among many other tasks.

The European Commission is supporting the development of assistive robots by investing in collaborations that bring together research institutions, small and medium-sized enterprises and target user groups with the aim of bringing these solutions to the market as soon as the technology and the law allows it. Annually, large sums of funds are destined towards these projects which certainly accelerate the development rhythm in this field and close the gap between the present situation and desired outcomes.

This work will also explore the existing challenges affecting the development of the robotics industry as well as its integration in the assistive and healthcare fields. The thesis looks to analyze if, based on the existing studies, the above-mentioned integration would be something that will happen in a short or a long term or if it would be convenient or practical to make it happen at all.

2 Methodology

The topic of the development of assistive robots and their implementation to the elderly care is relatively new, and due to the human condition of fearing the unknown, opinions about this topic can be emotional or influenced by the media. In order to avoid relying too heavily on biased sources, this thesis has been conducted based on the analysis of available qualitative data from existing studies.

3 Historical Development of Robots

Throughout history, humankind has been curious about the concept of machine-like companions. The very first signs date back to the ancient mythology where the Greek god Hephaestus creates a bronze man, Talos, to protect the Crete island (Cave and Dihal 2018: 473-474). Early evidence about human like machines could also be found in urban-legends of India and China among others.

In Homer's Iliad, Aristoteles contemplates that, in the future, the end to slavery could be brought by the automata. He understood that humans depend largely on the capabilities of machines and believed that if machines could do more work, there would be less left for humans, thus the end to slavery would be brought by the automata eventually (Messerly 2014).

One of the very first evidence of a robot design dates back to approximately 1495, and it was made by Leonardo da Vinci (1452–1519). According to the drawings, it was a knight armor that was supposed to walk, sit, move its arms and head. The drawing was discovered in 1950s and the reconstructed model, based on his drawing can be found in Berlin (Guarnieri 2010: 42-43).

During the 18th century, the advancement of automata continues through different creations such as Jacques de Vaucanson famous "The Digesting Duck" that was seemingly able to eat and digest grains, and also, his automated musicians: the flute player and the tambourine player (Andrews 2014).

The modern terminology of the word “Robot” was used for the first time in 1923 by Czech writer K. Čapek in his play ‘Rossum's Universal Robots’ (Christoforou and Müller 2018). However, in Slavic languages the term “Robota” was not new, it had been previously used for people who were forced to carry out obligatory service for the feudal system during the 19th century (Markel 2011).

Every new robotic invention led towards more researching, inventing and exploring on the field. We can argue that the concept of “a robot” was created through these artifacts, although the development of robotics had to wait until the 20th century to truly achieve its splendor.

4 Market situation: An ageing population

Thanks to the continuous development of socioeconomic procedures and public healthcare the populations of many countries have nowadays begun to enjoy of a longer-than-ever life expectancy. The elderly are living a more prolonged life, desiring to maintain autonomy for a longer period and to continue living in their own homes by themselves. Nevertheless, it is worth mentioning that living longer does not necessarily mean that a person would be able to fend for him or herself. Therefore, in many cases, a senior citizen will require external assistance in their daily activities.

The European Commission 2015 Aging Report points out that based on the UN World Population Prospects and in comparison, to other continents, Europe has currently the highest old age dependency ratio (Figure 1). It is forecasted that Europe will maintain the position until 2100 when Latin America is believed to surpass (European Commission, 2015a: 29).

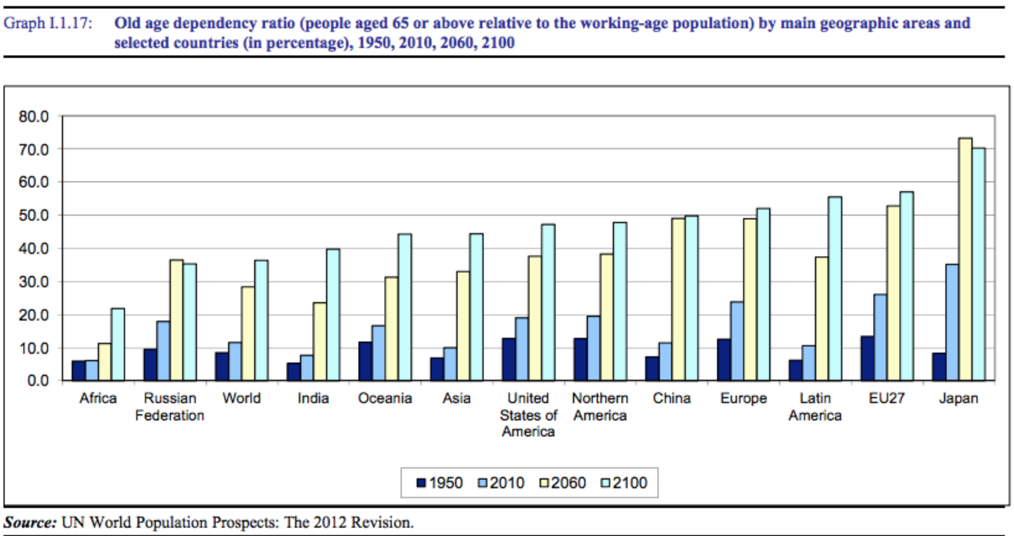

Figure 1. The comparison of old age dependency ratio around the world

In January 2017 the estimated population of the EU-28 was 511.5 million people. Within these numbers, young people between the age 0-14 made up 15.6%. The group of working people that is considered between the age 15-64 was 64.9%, and the elderly aged 65 or above counted for 19.4%. Compared to the statistics from 10 years before (2007), the increase of elderly people (aged 65 or above) was 2.4% (Figure 2) (Eurostat 2018a).

Population age structure by major age groups, 2007 and 2017
(% of the total population)

	0–14 years old		15–64 years old		65 years old or over	
	2007	2017	2007	2017	2007	2017
EU-28 (¹) (²)	15.9	*15.6*	67.1	*64.9*	17.0	*19.4*
Belgium (¹)	17.0	17.0	66.0	64.6	17.1	18.5
Bulgaria	13.2	14.1	69.1	65.2	17.6	20.7
Czech Republic	14.4	15.6	71.1	65.7	14.5	18.8
Denmark	18.6	16.7	66.1	64.3	15.3	19.1
Germany (¹)	13.9	13.4	66.3	65.4	19.8	21.2
Estonia (¹)	14.9	16.2	67.9	64.4	17.3	19.3
Ireland (¹)	20.3	21.1	68.9	65.4	10.8	13.5
Greece	14.7	14.4	66.7	64.0	18.6	21.5
Spain	14.6	15.1	68.9	66.0	16.5	19.0
France (¹)	18.5	*18.3*	65.2	*62.5*	16.3	*19.2*
Croatia (²)	15.6	14.5	66.7	65.8	17.7	19.6
Italy	14.1	13.5	65.7	64.1	20.1	22.3
Cyprus	18.9	16.3	68.8	68.1	12.4	15.6
Latvia	14.2	15.6	68.4	64.6	17.4	19.9
Lithuania	16.0	14.8	67.3	65.9	16.6	19.3
Luxembourg (¹)	18.3	16.2	67.7	69.5	14.0	14.2
Hungary (¹)	15.2	14.5	68.9	66.8	15.9	18.7
Malta	16.6	14.1	69.5	67.0	13.9	18.8
Netherlands	18.1	16.3	67.4	65.2	14.5	18.5
Austria	15.6	14.4	67.5	67.1	16.9	18.5
Poland (¹)	15.8	15.1	70.8	68.3	13.4	16.5
Portugal	15.7	14.0	66.7	64.9	17.5	21.1
Romania	16.9	15.6	68.4	66.6	14.7	17.8
Slovenia (¹)	14.0	14.9	70.1	66.2	15.9	18.9
Slovakia	16.2	15.5	71.8	69.5	12.0	15.0
Finland	17.1	16.2	66.5	62.8	16.5	20.9
Sweden	17.0	17.6	65.6	62.6	17.4	19.8
United Kingdom	17.8	17.8	66.3	64.1	15.9	18.1
Iceland	21.3	19.7	67.1	66.2	11.6	14.0
Liechtenstein	17.1	14.9	71.0	68.2	11.9	17.0
Norway	19.4	17.8	66.0	65.5	14.6	16.6
Switzerland (¹)	15.8	14.9	68.1	67.1	16.2	18.1
Montenegro	20.1	18.2	67.0	67.4	12.9	14.4
The former Yugoslav Republic of Macedonia (²)	18.9	16.6	69.8	70.2	11.2	13.3
Albania	24.9	18.2	66.3	68.7	8.8	13.1
Serbia (¹)	15.6	14.4	67.2	66.3	17.2	19.4
Turkey	26.6	23.7	66.6	68.0	6.8	8.3

(¹) Break in time series in various years between 2007 and 2017
(²) The population of unknown age is redistributed for calculating the age structure.
Source: Eurostat (online data code: demo_pjanind)

Figure 2. The changes in the EU population age structure from 2007 until 2017

Clearly this situation does not affect equally all of the countries; some have a more imminent need for a solution than others. In some cases, the disproportion in the ratio between the working force and the elderly is noticeably large to the point of becoming easily unsustainable while others remain more balanced for the time being.

According to Eurostat, in 2017, the highest number of young people were in Ireland with 21.1% of the country's total population. Across the EU Member States, Germany had the lowest share of young people with 13.4% of the country's total population. Regarding the age group of 65 and above, in 2017, Italy had the highest share among all the EU Member States with 22.3% while in Ireland, the same age group represented only 13.5% of the country's total population (Eurostat 2018b).

Regardless of the fact that population ageing is a worldwide matter of contention, as mentioned before, some countries face this issue sooner than others. For example, for Taiwan's population it took 25 years to become an aged society, starting from 1993 to 2018, while the United States reached the same point in 71 years and Sweden in 85 years (Chou, Wang and Lin 2018: 1).

In many countries, employees in the healthcare sector, especially nurses and caretakers for elderly people are often underpaid, making these professions unattractive and resulting in increasing demand for the workers that are left. Based on research of the US Bureau of Labor Statistics, it is predicted that only in the United States, by 2020 there will be a need of 70 percent more employees in the field of household assistants (Bogue 2013a: 519).

In addition to the growing need for caregivers, stroke-survivors is also a group that often needs life-long support and assistance. In Europe, strokes are one of the major causes of disability among the elderly. Only in Europe, there are approximately 6 million stroke occurrences every year, and 1.1 million of these incidents are caused by first stroke. Based on the statistics, approximately 75% of stroke victims will survive the year after. Approximately 80% of these patients will experience enduring loss of manual capabilities and almost half of this number will need support with their daily tasks for the rest of their lives (Béjot et al. 2016).

In Europe, according to the demographic changes that predict longer life expectancy and reduced birth rates, it is estimated that there will be a dramatic change in the ratio between the amounts of workers and elderly people. In 2012 the ratio was 26.8% (approximately one elderly person to four workers), but by 2060 it is expected to be 52.6% (one elderly person to two workers) (European Commission 2013a). As a result of this, the cost of health and social care for seniors will undoubtedly rise due to increasing demand and a shortage of labor force supply.

5 Assistive Robots

In the field of robotics, there are currently missing defined standards for the classification of assistive robots. In order to avoid possible confusions, the focus of this research will be directed towards to main categories: Physically Assistive robots and Socially Assistive robots.

5.1 Physically Assistive Robots

Even though in academic literature there is still not a clear definition and categorization of what assistive robots are, there are different descriptions distinguishing various types of these robot classifications. One of the most widely used and cited explanations describes Assistive Robots as those that provide aid to users through physical interaction. There is a wide sector of robots whose objective is to help people in different tasks such as getting dressed, eating, grasping objects, opening doors, recovering from injuries and many more. These robots are designed to help people to complete tasks that are either challenging or impossible for the particular user to perform without external help (Feil-Seifer and Matarić 2011a: 2).

In the field of assistive robots, there are available various models that can be used for different purposes to aid people with reduced mobility. One example is the Cody robot (Figure 3), developed at the Healthcare Robotics Laboratory at Georgia Institute of Technology, it is designed to help with the bathing of an individual. Cody is equipped with two compliant arms built to simulate brushing motions with a soapy mitt to assist users with bathing. A camera and a laser rangefinder first detect the area that needs to be cleaned and then the robot gently washes the selected area. This particular robot aims to avoid the use of a caregiver during the bathing time for patients that do not have a severe reduced mobility, therefore granting a bit more of independence, privacy and, until certain extent, self-esteem (King, Chen, Jain and Kemp 2010: 1-6).

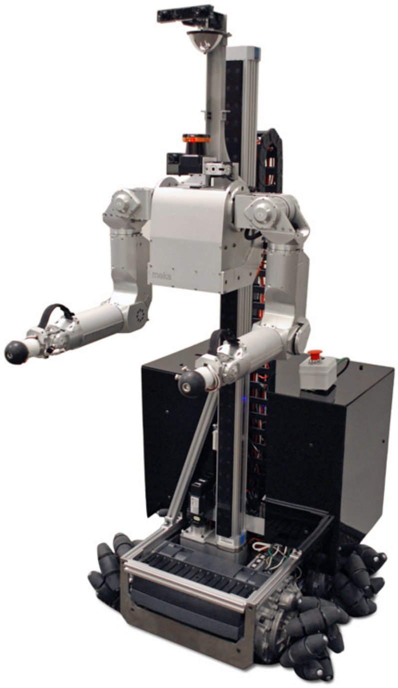

Figure 3. Cody robot, developed at the Healthcare Robotics Laboratory at Georgia Institute of Technology

The incapability to eat without the help of a nurse or caregiver is one of the most common issues among disabled people. The Korea National Rehabilitation Research Institute has developed a self-feeding machine to help patients to eat without another human's assistance. This machine is a dual-arm robotic manipulator (Figure 4) that is able to feed a patient not only with a spoon and chopsticks (Bogue 2013b: 522).

Figure 4. Self-feeding robot developed by Korea National Rehabilitation Research Institute

Possibly the best-known type of assistive robot is the mobile-wheeled platform with touchscreen and arms for tasks that require handling objects. A good example is the Care-O-bot (Figure 5) that has been produced by a Fraunhofer IPA, in Germany. Its continuous improvements demonstrate well how rapid has been the development of assistive robots. The first prototype of Care-O-bot was made in 1998 and it was able to navigate in crowded environments. It had a touch screen, but not arms that could perform manipulation tasks. Care-O-bot II was introduced in 2002 and one of the main differences compared to the first model was the manipulator arm that was able to perform simple tasks, such as grasping objects. For an improved environment perception, it had two cameras and a laser, in addition to that, it was able to provide walking support for the users. Care-O-bot III was introduced in 2008, with significantly improved design and operational capabilities. It also included a tray that could be used for different purposes, such as carrying objects or eating. The current and latest model, the 4th generation, Care-O-bot 4, became available in 2015. Compared to the previous models, it was more modular - it could have two arms, or one could be replaced by a tray to serve beverages etc. It was also available with no arms. (Fraunhofer Institute for Manufacturing Engineering and Automation 2018).

Figure 5. The latest model of Care-O-bot 4 robot, with two manipulative arms

A particular type of assistive robot is the Exoskeletons. This category covers a wide range of application areas involving injury recovering, manual labor and walking assistance among others. A particular kind of exoskeleton (Figure 6), can help patients who have lost the ability to use their legs or who have suffered a spinal cord injury, to gain a significant autonomy. Exoskeletons can also be used by people who work in positions where daily tasks could cause health injuries. For instance, in the United States, in the Ford assembly plant some of the employees are using exoskeletons to prevent shoulder injuries while performing repetitive overhead tasks. (Dearborn 2018) (Figure 7). In Japan, where there is a higher shortage of healthcare workers, exoskeletons are used by employees who need to lift and carry elderly people (Figure 8). Usually it is required that multiple people complete this task, but with the help of the exoskeleton, only one person is required to provide the needed assistance.

Figure 6. Exoskeleton, Assistive Limb, developed by Cyberdyne

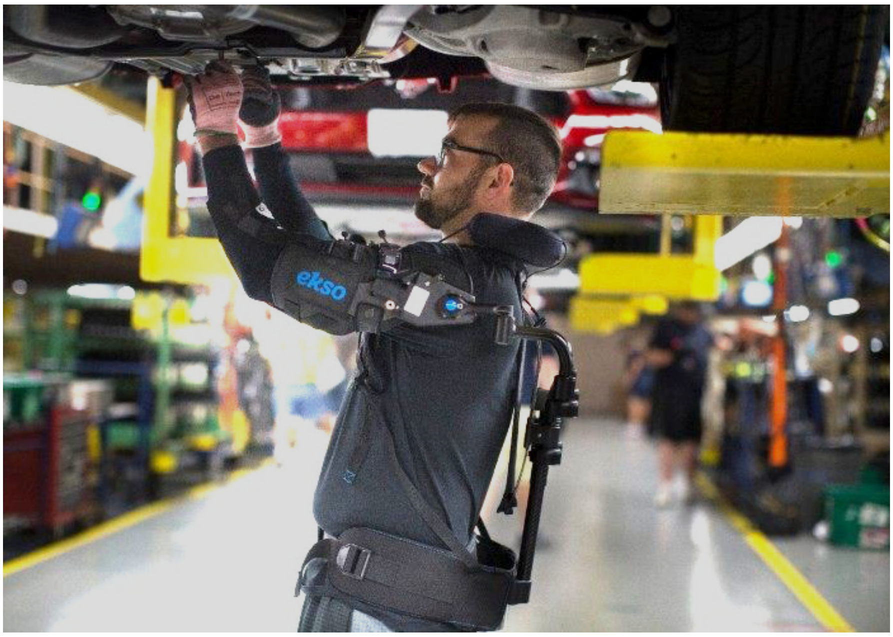

Figure 7. Exoskeleton, the EksoVest, used by the assembly line workers in the Ford factory to prevent shoulder injuries caused by the overhead work

Figure 8. Japanese healthcare worker using Exoskeleton suit to support and help while lifting elderly people, task that usually requires assistance from multiple people

5.2 Socially Assistive Robots

Socially assistive robotics is the segment of the industry that is aimed to help the users, mainly without physical assistance. They provide coaching, supervision and help to improve motivation through automation. They can be compared to a trainer or a teacher that provides theoretical and psychological assistance, support, motivation and guidance. The development of socially assistive robotics aims to bring relief to the growing demand for healthcare workers that provide assistance, not only to elderly, but also to patients with reduced mobility, people with slight dementia and children with autism (Feil-Seifer and Matarić 2011b: 2).

Social robots are designed to interact with people in a personal manner through the provision of help and support in daily tasks; they are often considered as human companions. Even though they are commonly built as humanoids or resembling animals, there are also simpler designs that do not appeal to any particular perception. The main importance of this type of robots remains the capability of providing support regardless of any particular look (Siciliano and Khatib 2016: 1936).

An example of socially assistive robots is the PARO, it was developed by a Japanese company AIST, and it has been available on the market since 2003 (Figure 9). By its appearance, PARO resembles a baby seal and it is responsive to touch. It has different sensors that help to recognize people and the environment. In addition to that, it is capable of learning according to its user’s preference and even react to its own name. PARO can move its tail, head, legs and also make sounds and due to that, it appears truly alive (PARO Robots US., Inc. 2014).

Figure 9. PARO robot that looks like a baby seal helps to decrease loneliness of elderly people

Recent studies in Italy show that animal therapy has positive effects on the residents by reducing depression symptoms and restlessness. One of the main limitations of animal assisted therapy are safety, hygiene and the availability of suitable animals. In most of the healthcare institutions and senior houses animals are not allowed. Due to that, robots, especially pet robots like PARO have become a considerable alternative in this type of treatment (Birks et al. 2016).

PARO robot has been used in numerous researches in healthcare institutions and senior homes. As a common outcome of the many studies carried on healthcare institution and senior homes where PARO has been introduced, there has been a positive effect on increasing social interaction between patients and decreasing the feeling of loneliness (Bennett et al. 2017).

AIBO (Figure 10) is another dog-like socially assistive robot that has also been used in researches with the elderly. It was developed by Sony and became available on the market on 1998 until the company decided to discontinue production in 2006. In January 2018, in Japan, Sony launched the fourth generation AIBO (Stenhouse 2018). Research in Japan among elderly people with severe dementia, using AIBO as occupational therapy, showed that the application of this robot increased social communication among the patients and with the robot itself. In addition to that, it brought up good memories from earlier stages on the patients' lives (Tamura et al. 2004: 83-85).

Figure 10. 5th generation AIBO robot

Another type of robotic platform frequently used in projects dedicated to assist the elderly in their homes or senior facilities are usually mobile platforms with wheels that have a touch screen for the user interface. The main features for this type of platforms include options such as telepresence, reminders for taking medicine or the next appointment with a doctor. Some of the more advanced models can be extended with add-ons that offer users the possibility to use thermal camera for monitoring body temperature or RFID tag reader, that help to locate items in the household.

One of these platforms is the Kompai-1 robot (Figure 11), developed by a French company named Robosoft, and launched in 2009. The first model had the main characteristics, like reminders for taking medicine, navigating autonomously, talking and understanding speech. In addition to that, with the videoconference option it was able to connect with a doctor or family members in real time. In 2016 Kompai launched their second assistive robot that had the main features, but as an upgrade offered walking support for more safer navigation for the elderly (Kompai n.d.).

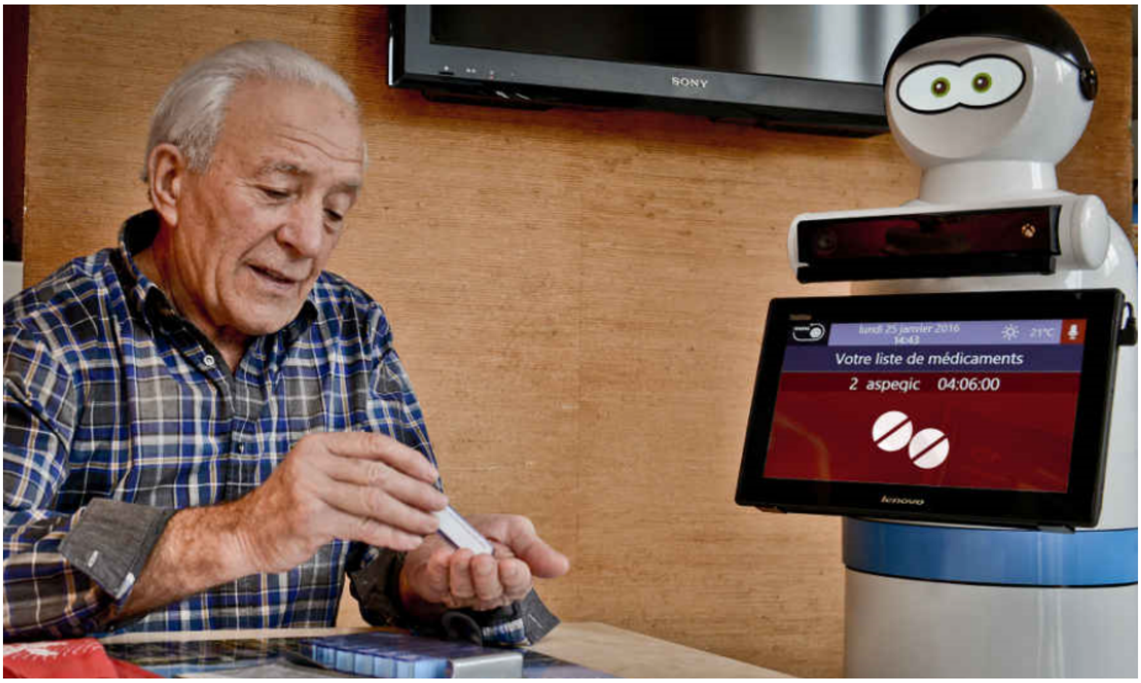

Figure 11. Kompai robot supports the independent living of elderly people

5.3 Application areas for Socially Assistive Robots

Created with the main purpose of meeting the needs of those who require special care, assistive robots have been introduced to function in diverse environments, including the health, education and senior-care sectors, as well as in daily-life routines in a private home (Feil-Seifer and Matarić 2011c: 2). A great advantage with the development of socially assistive robots is their possible application in areas such as:

1. Elderly care.
2. Rehabilitation and physical recovery.
3. Care for people with cognitive disabilities.

5.4 Rehabilitation and recovery

Studies have demonstrated that failing in continuing a rehabilitation exercise routine is often related to decreased motivation in a patient. A socially assistive robot can provide patients with resolute encouragement, guidance, monitor the day-to day physical progress and provide feedback based on the results of completed session.

The implementation of assistive robots in rehabilitation treatments would bring along a varied number of advantages to the patients. A robot would offer physical support for heavier weights and longer periods that a human could, it would be used for a more accurate evolution progress monitoring including feedback gathering from the patient performances. Ultimately, assistive robots could help to reach faster the point where a patient can do his or her rehabilitation treatment in an independent way without the need of another person (Halcyon Dialogue 2016: 18). This integration would also propitiate a scenario where patients do not even need to leave their houses if they can afford to have the technology at home.

5.5 Socially Assistive Robots for children with cognitive disabilities

Researchers have demonstrated that the implementation of socially assistive robots in therapy can be used not only for the elderly, but also, for treating autistic children (Figure 12). Multiple studies have indicated a greater impact leading to more positive results when combining this new technology with conventional treatments.

A study conducted by a group of researchers from Yale University, tested 3 different types of treatments among children between the ages of 4-12 who were suffering Autism Spectrum Disorder (ASD). Based on this study, children became more vocational and engaged when interacting with an animal looking socially assistive robot compared when interaction with an adult or a touchscreen computer game (Kim et al. 2012: 1044-1046).

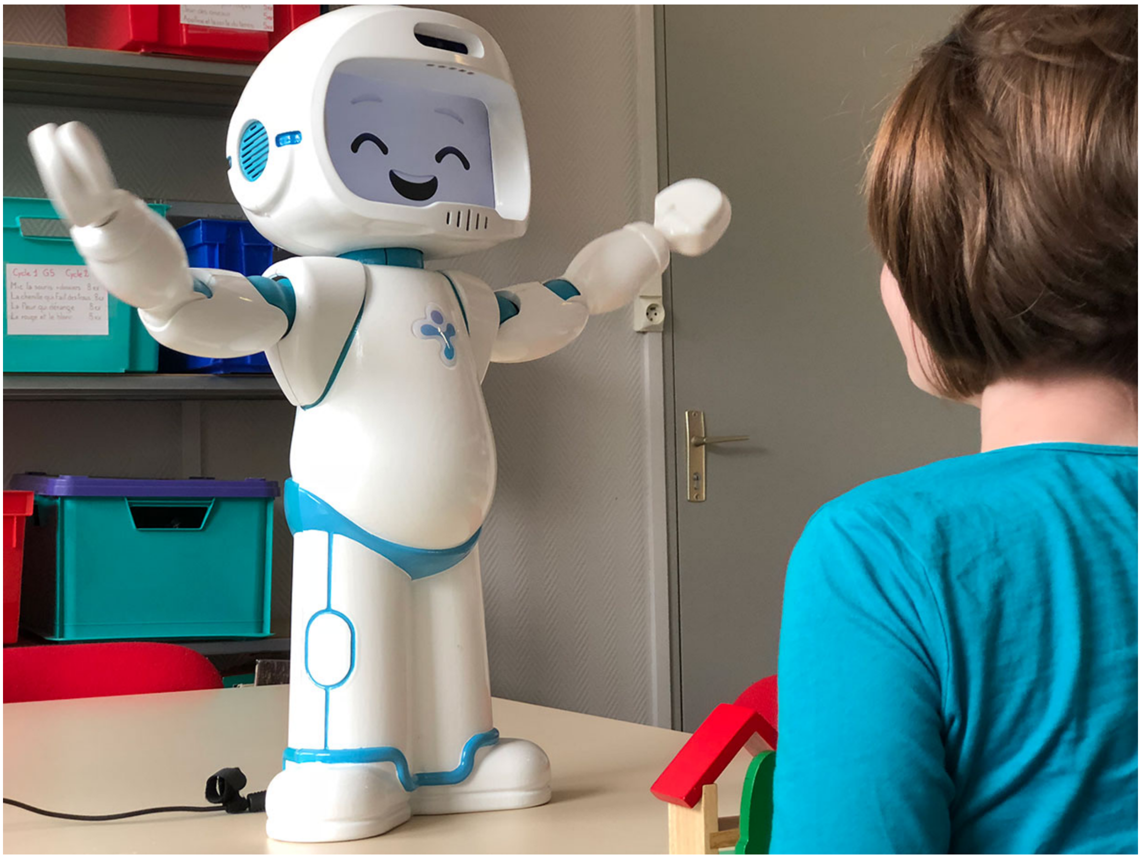

Figure 12. Socially Assistive Robot (SAR) for the therapy of children with autism spectrum disorder

Based on the statistics of the World Health Organization, around the globe there are approximately 10% of children and young people (approximately 200 million) with sensory, intellectual or mental health issues. Many of these children need lifelong assistance, which results in high healthcare costs (SPARC, 2016a: 151).

Statistics in the United States showed that in 2014, 1 out of 68 children was diagnosed with the Autism Spectrum Disorder. Compared to the previous study that was completed in 2012, the results were 1 out of 88, showing a 30% increase. The reason behind this is still unknown, but this also indicates that there will be a higher demand for healthcare workers who will be able to provide long-term support. Many of these children will need support through their lives. Implementing socially assistive robots in courses of therapy and also for care provision can bring relief of the caregivers' demand (The Centers for Disease Control and Prevention 2014).

6 Development of Assistive Robots through Public-Private-Partnership in Europe

During the recent past the development of robotics has been flourishing like never before. The European Union invests annually in this industry with the aim of seeing it progress at a faster rhythm. Many of these projects are dedicated to tackling technical issues related to the development of the functionality, design and feasibility of pricing when developing and implementing new robots. Projects like Inbots addresses matters with the creation of standards and a legal framework for the robots that interact with humans (Inbots 2018).

A significant part of this subject is the creation and work of such organizations as the SPARC. Today these assemblies mark an important role for European Commissions with their contribution for advisory guidelines that direct the European Union with the decision making and investment regarding the assistive robotics.

6.1 euRobotics AISLB

The euRobotics AISBL (Association Internationale Sans But Lucratif) (see Figure 13) has developed a groundbreaking project named SPARC. This project emerges seeking to foster the development of these new technologies and the continuous integration of robots into different industries.

A more detailed description of this cooperation's main goals has been defined by both AISBL and the European Commission and are summarized as follows:

- strengthening competitiveness and ensuring industrial leadership of manufacturers, providers and end users of robotics technology-based systems and services;
- the widest and best uptake of robotics technologies and services for professional and private use;
- the excellence of the science base of European robotics (euRobotics AISLB n.d).

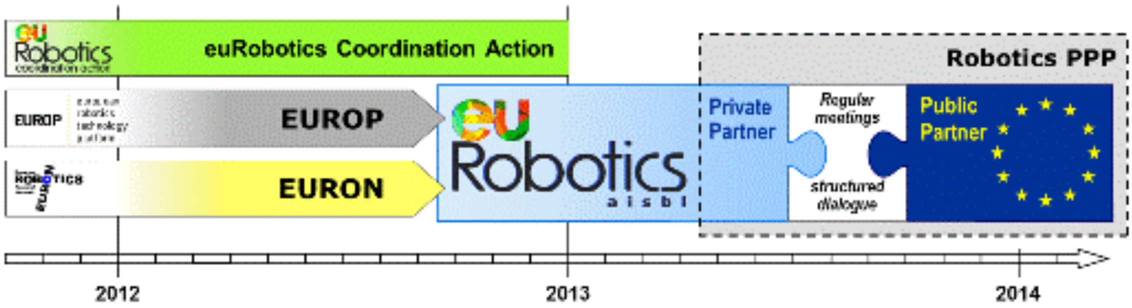

Figure 13. euRobotics AISBL as a part of public-private-partnership in Europe

6.2 SPARC, driving the Public-Private-Partnership in Europe

Launched in 2014, SPARC is the Public-Private-Partnership between the European Commission and AISBL. This programme looks to foster the integration of European robots into any market branch or industry that could have an economic and societal impact in the continent. SPARC aims to maintain and extend the current, leading position of Europe in this industry which by holds 32% of the global share on the industrial robots' sector, and a 63% of the shares in 2018 on the service robotics market (SPARC 2018).

Based on SPARC's projections of the robotics market, their continuous action on the public-private partnerships can have a significant impact on Europe's global market share, and therefore in the revenues obtained from this this industry (Figure 14), SPARC speculates that thanks to their input there can be achieved an extra 14% of European market shares globally. That would correspond approximately to an additional €44bn in robotics expenditure between 2014 and 2020. It is important to highlight that the estimates of the application of advanced robotics in healthcare, manufacturing and services point to a generous global annual economic impact of approximately $1.7 trillion and $4.5 trillion by 2025 (SPARC 2016a). Therefore, pioneering in this industry could mark a decisive advantage against the competition, making companies more agile when reacting towards new technologies.

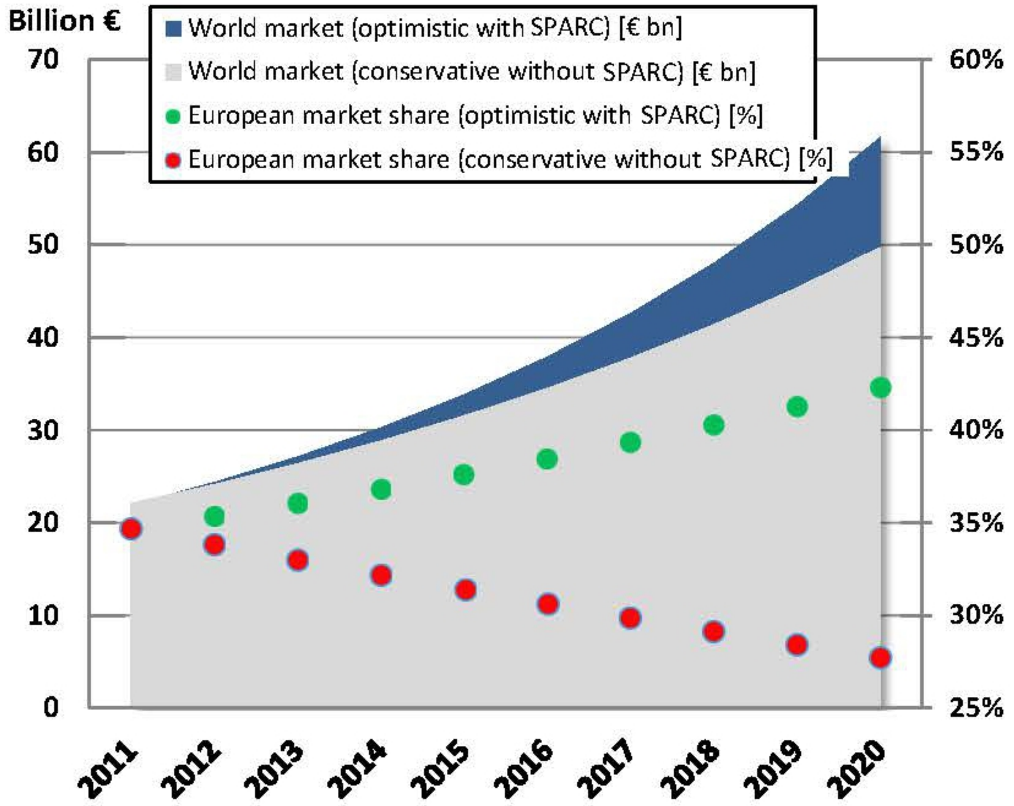

Figure 14. The projection of the development of robotics market in Europe with and without the participation of SPARC

Over 250 affiliate organizations from Europe work together on this programme to achieve a strategic position for the continent's robotics in the world. Every year SPARC updates a multi-annual roadmap, created by specialist from euRobotics AISBL associate organizations, to guide which investment in robotics could bring the most benefit in economic and social terms. The objective of this roadmap is to provide a detailed technical guide identifying expected progress within the community which will derive a list of funding recommendations for the Commission of Horizon 2020 Robotics programmes (SPARC 2016b).

6.3 Horizon 2020

Horizon 2020 is the programme developed by SPARC that acts as a dedicated financial instrument in order to drive research and innovation to secure Europe's competitiveness on a global scale. It aims to diminish the gap between research and the market by supporting innovative companies to develop viable products and services that can be brought to the market. Among Horizon 2020's main priorities are research and innovation to support solutions to the health, well-being and demographic challenges in Europe (European Commission 2018a).

Under the Horizon 2020 programme (2014-2020), the European Union is investing approximately €80 billion for the R&I projects with the goal to improve the lives of its citizens. According to the Horizon 2020 report, the division of investment in robotics goes accordingly: 55% to industrial and 45% to research projects (SPARC 2016c) (Figure 15).

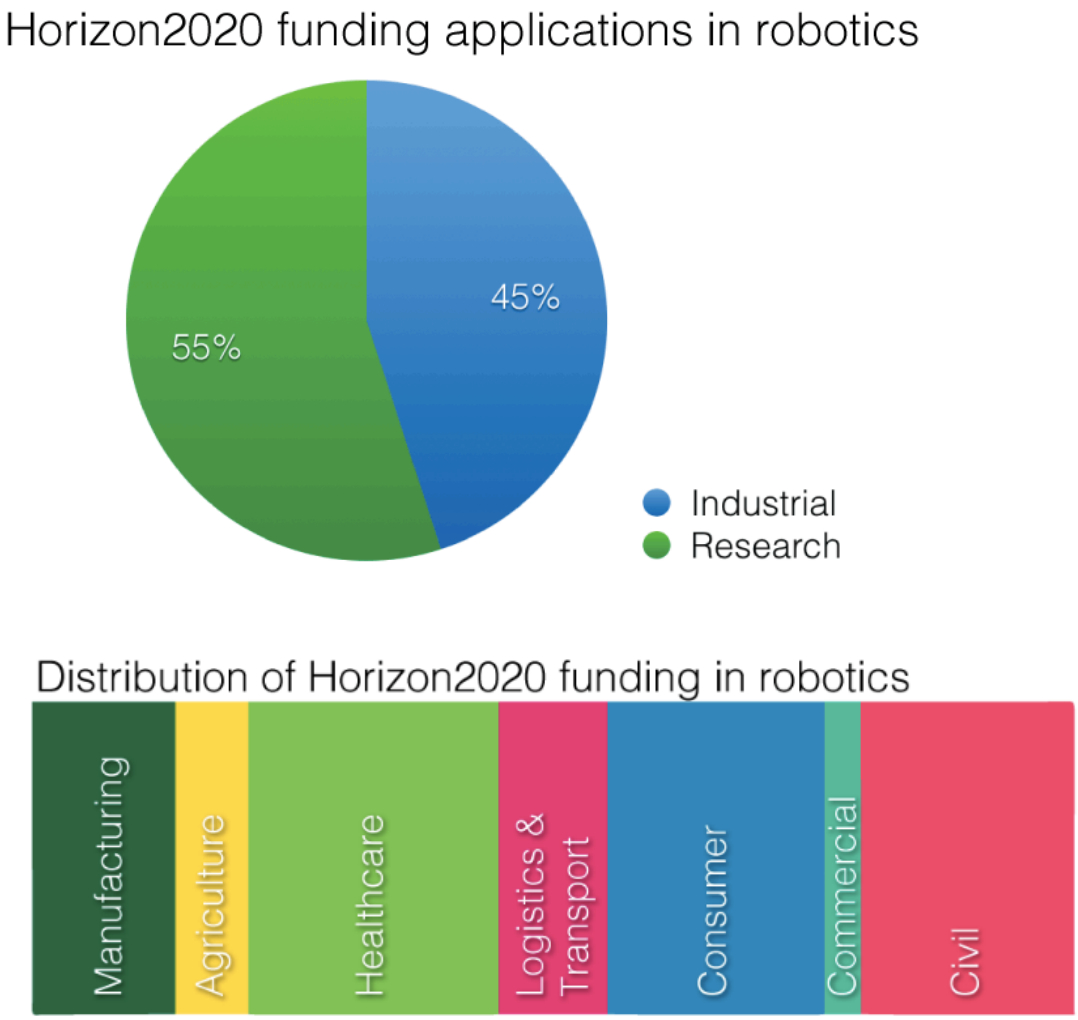

Figure 15. The division of investment in robotics under the Horizon 2020 program from 2014 until 2020

6.4 The Active Assisted Living Programme (AAL)

The Active and Assisted Living Programme (AAL) is one of the most extensive in Europe that funds projects that develop products and services involving technology in order to attend the needs of older people and achieve an active and healthy ageing. The objective for the AAL Programme is to improve the living conditions for elderly people while supporting the SMEs to increase their international business opportunities in the ICT field (European Commission 2018b).

During the 1st phase of the AAL project that took place between the years from 2008 to 2013, 154 projects, within 6 calls were funded. The planned budget for the programme was 600 M€, where 50% public funding that came from the European Commission and from the partner states of AAL Programme. The remaining 50% was contributed by the participating organisations and was private funding (AAL Association 2015a: 3-172). A

AAL started in 2008 and it was initially named Ambient Assisted Living Programme. After its successful completion in the 2013, it was renewed for a second time with a new name of Active and Assisted Living Programme (AAL). Its second part takes place from 2014 until 2020 being co-financed by Horizon 2020 and the European Commission and ran by the Member States of the European Union (European Commission 2017b: 10).

The AAL achievements include:

- Prolonging the period people can live in their preferred environment by improving their autonomy, boosting self-esteem and mobility.
- Preventing social isolation and securing a multifunctional network for the individuals.
- Securing support for the caretakers, for the family and care organizations.
- Promoting active and healthy lifestyle for elderly.

Some examples of the completed robotics projects and their objectives are listed below:

- **ALIAS**
  Started on 1st of July in 2010 and lasted 36 months.
  Total budget: 4 022 075€
  Public contribution: 2 529 165€
  Goal: Development of 2 assistive robots, where 1st was for domestic environments to provide support in emergency situations and for keeping contact with family/friends. 2nd platform was developed for nursing homes for reminding medication, telepresence, cognitive training and for entertainment. In this project, 160 end-users were involved.

- **EXCITE**
  Started on 1st of July in 2010 and lasted 30 months.
  Total budget: 2 853 701€
  Public contribution: 1 448 430€
  Goal: Development of mobile robot telepresence (MRP) device for social interaction in the household of elderly. EXCITE project used the Giraff telepresence platform from Giraff Technologies AB. This project was awarded with the AAL JP Most Promising Project award in 2011.

- **EXO-LEGS**
  Started on 1st of October 2012 and lasted 36 months.
  Total budget: 4 559 117€
  Public contribution: 2 776 346€
  Goal: to develop exoskeletons for the lower body mobility that would provide user help with moving around and performing their everyday tasks

- **VICTORYAHOME**
  Started on 1st of April 2013 and lasted 36 months.
  Total budget: 2 366 201€
  Public contribution: 1 308 284€
  Goal: Developing telepresence robot with a service to connect remotely elderly people living at their homes with professional care givers. The robot can be used also to remind different tasks such as, to take medicine or to drink water.

- **AXO-SUIT**
  Started on 1st of May 2013 and lasted 36 months.
  Total budget: 2 978 018€
  Public contribution: 1 676 516€
  Goal: Developing exoskeleton for elderly to maintain mobility (AAL Association 2015b: 3-172).

Based on the second phase of the mid-term report of the of the AAL program, it was recognized that for the future development there needs to be even a closer link to the market and in addition there should be continuous engagement with the end-user to assure the relevance of newly developed solutions (European Commission 2018c).

6.4.1 An example of Assistive Robot projects in the AAL programme

In order to appreciate better how the projects regarding the development of assistive robots are conducted and executed, and about the type of insights they can provide, here is a description of the process of creation, development and conclusion of the ENRICHME programme.

The ENRICHME (Under the Horizon 2020) started in March 2015 and finished in February 2018. This period included also the pilot trials that took place in 3 different European countries. The total budget for this project was of 3 991 940€. The ENRICHME system was an interactive mobile robot integrated into a domestic ecosystem (assisted living environment) to provide advanced services for the users. It was coordinated by Elettronica Bio Medicale S.p.A. and it had a consortium of 10 partners from 7 different European countries. Partners were researcher groups from universities, healthcare institutions and SMEs developing robotic solutions such as hardware and software (The ENRICHME Consortium 2015a).

Project Objectives:

1. Improving the life quality of elderly people who are suffering Mild Cognitive Impairment (MCI). Using a socially assistive robot in an ordinary living environment to help reduce the risks that might exist due to the MCI condition.
2. Evaluating the learnability and acceptability of the robot and the AAL services by the elderly (target group), their relatives and caregivers.
3. Evaluating the potential of the ENRICHME programme to improve the health care organizations' personnel and time involvement, including the cost/benefits.
4. Developing a 24/7 non-invasive monitoring system for the elderly at home in order to detect changes in behavior and to minimize the risk of dangerous situations.
5. Developing effective analysis methods for the interpretation of non-invasive physiological measurements and their association to short- and long-term human activities, including data fusion and evolution trends aspects.
6. Developing appealing solutions for Human-Robot Interaction (HRI) that are also able to learn and adapt to the user in terms of cognitive and perceptual capabilities. It would include the capability of offering non-pharmacological treatment and assistance for social involvement.

6.4.2 Pilots

During a 7-month period, pilots of the programme took place in 3 different countries. Each testing site was equipped with 2 ENRICHME systems (robotic platforms). The elderly people who participated in the project were living independently in a senior house and used the ENRICHME programme continuously during a 3-month period. ENRICHME system with 3 different intelligence levels (see Figure 16) (The ENRICHME Consortium 2015b).

1. Robot Intelligence
2. Ambient Intelligence
3. Social Intelligence

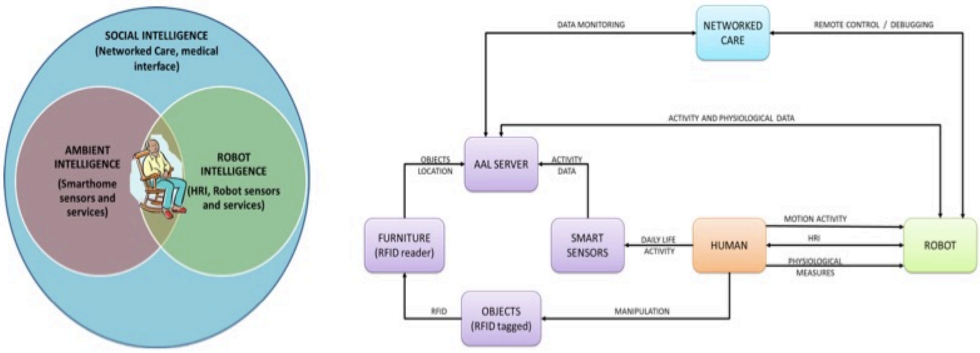

Figure 16. The 3 different intelligence levels in the ENRICHME system

6.4.3 Data collection

The data of the ENRICHME project (Figure 17) was collected through in-session and after-session observations including qualitative and quantitative questionnaires. In addition to these, the test sessions were video recorded for a deeper analysis of the users' behaviour and for the evaluation of the required time to complete the assigned tasks. Elementary statistics (correlation, standard deviation, means values, etc.) were used for the analysis of the results and the feedback of the questionnaires.

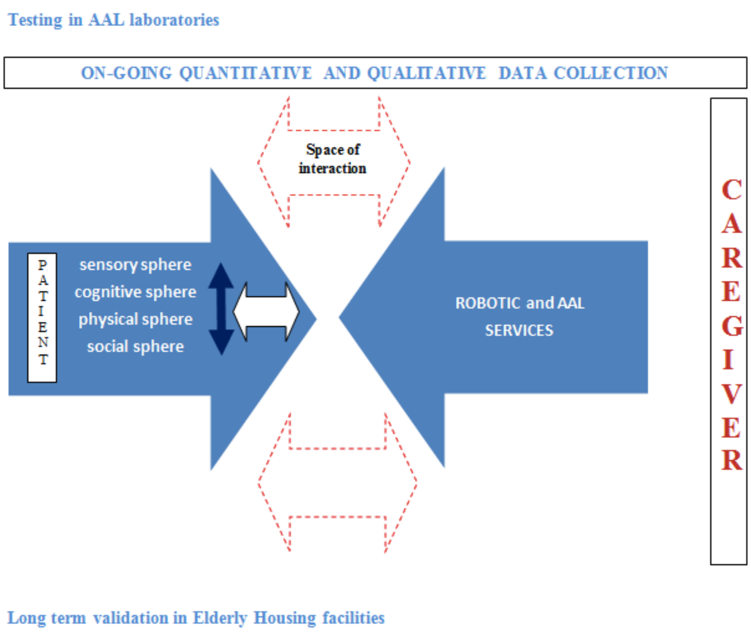

Figure 17. The data collection in the ENRICHME project

The data was also collected through two in-depth analyses that took place at the AAL laboratories and in the senior homes. The aim of the first test was to collect users' feedback that would help to improve the final prototype, especially regarding the requirements for technological improvement. The second test, completed at the senior home, was aimed for the assessment of the platform strengths and weaknesses of the prototype (The ENRICHME Consortium, 2015c).

6.4.4 ENRICHME project results

The results of this type of project provide valuable insights regarding the development of assistive robots. They help to identify the main challenges with the platforms used and analyze the general perception and acceptance by the end users, which in this case were the elderly and the caregivers.

The results of the ENRICHME Project demonstrated that the robot was able to successfully support the daily activities of the elderly people and provide

Based on the ENRICHME Impact Assessment report the project was able to reach the set objectives 1, 2, 4 and 6. The accomplishment of these set objectives gave insights on how the project influenced the primary and secondary users. According to the primary users who were elderly people, the use of the assistive robots helped them to improve their mood, mobility and to feel safer. The users felt an improvement of their life quality, gained more independence and their feeling of loneliness decreased. In addition, the compliance with medical prescriptions, such as remembering to take pills and scheduling appointments with the doctor was improved. The results of this experiments proved positive towards the possibility of implementing an assistive robot on the daily lives of elderly people suffering from MCI.

The secondary users, the caregivers and the assistance personnel of the senior house facilities, stated that the system is a good reminder of scheduled activities. Nevertheless, they found it challenging to integrate in the daily routine of the elderly. The project results highlighted that it took time to adapt the robot into the care facility and to learn how to use the system. The report also brought out that the caregivers' lack of motivation and their aversion towards a new system can be possible barriers for the adaptation of new systems (European Commission, 2018d).

7 The main challenges with Assistive Robots

Along with the rapid development of assistive robotics, some problematics have arisen that might influence the possible future integration of these technologies into our daily lives. The main dilemmas that occur in numerous researches are related to different ethical questions; researchers have expressed concerns regarding the physical safety and privacy of the users in terms of data collection and handling. Surprisingly, this is not a new issue. Similar aspects had already been illustrated for the first time in 1942 by Isaac Asimov in his science-fiction book *Runaround* (Barthelmess and Furbach 2014: 1), where he recommended 3 laws for robot behavior:

1. A robot may not injure a human being or, through inaction, allow a human being to come to harm.

2. A robot must obey the orders given to it by human beings, except where such orders would conflict with the First Law.

3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

7.1 Ethical challenges

With the missing legislation for the assistive robots, ethical debates form a significant part of the ongoing discussions regarding the possibility of implementing these technologies into the daily lives of the elderly. Questions such as physical safety or privacy of users in terms of the data collection and handling raise concern among many researchers. These are just some of the issues alongside many others that need to be taken in consideration when creating a legal framework for the assistive technologies.

7.2 Privacy and data collection

The question of privacy seems to be one of the main worries on the use of assistive technologies that link to areas such as collecting data or how to assure safety of the user without interrupting their daily activities.

Some researchers speculate that it is not possible to guarantee privacy while being under real-time supervision as there is no way to decide what data will be shared (Zwijsen et al. 2011: 421a). The privacy issue with the adoption of assistive robots to the domestic environments of elderly people is considered to have such a high importance that it could even stop the acceptance by the end users (Mansouri, Goher and Hosseini 2017a: 2).

When creating any regulations for assistive technologies, it is highly important to consider possible risks related to data security. It is speculated that since assistive technologies could be accessed or hacked in such manner where the systems memory could be erased or stopped, this could cause severe dangers to the user's health or even to their life (Kritikos 2018a: 21).

The complexity with the data handling arises due to the debate of how robots will distinguish the correct information to share with the health care staff. Will the software programs identify efficiently between what is useful for the patient's treatment and what is a violation of their privacy? In a case where a private piece of information about the patient would be accidentally revealed, how many people would have access to it?

When putting into practice the type of processes that could involve collecting the users' daily well-being information, it becomes extremely important the collected data is handled complying the existing Data Protection Act.

With the new European General Data Protection Regulation, it is required that the user has the right to decide how the data is collected, archived or used. In addition to that, it is required that the traditional medical principles are followed, guaranteeing the patient privacy and safety (Kritikos 2018b: 17). In some cases, people who are eligible for the use of assistive robots, might present health issues that could influence their decision making. Due to that, laws regarding the use of these new technologies should be made in such manner that it takes inconsideration the more vulnerable user groups and make sure that their privacy will not be violated.

7.3 Autonomy

The possibility of gaining additional autonomy is a benefit that is often highlighted with the implementation of assistive robots to the daily lives of the elderly. Thanks to the use of assistive robots in domestic environments, many believe that the elderly could prolong their stay in their own homes.

However, some researchers have demonstrated concern stating that the addition of assistive robots could have negative repercussions. It has been speculated that due to the technical complexity of assistive robots or not knowing the abilities and limitations of a specific system, instead of gaining freedom, users might become more limited, as they are not fully aware of the extent of their own decision making (Feil-Seifer and Matarić 2011d: 12).

Another research speculates with the following possibility: if assistive robots would be able to detect hazardous situations, such as a stove left on or an overflowing bathtub, they could also be able to prevent them or to stop the elderly to carry out tasks that can be dangerous. This could result in users becoming controlled with their own decision making as the robot would be acting as an autonomous supervisor (Sharkey and Sharkey 2010a: 33).

7.4 Social influence

While studies related to the use of companion robots, like PARO for example, demonstrate a positive increase in social activity among users in the senior homes, many researches show concern regarding the possibility of elders adopting an isolating attitude, wanting to interact only with the robot instead of with any other human being.

On the other hand, the issue with the loneliness among senior citizens is a recognized topic in many countries around the world. There are researchers who believe that some of the elderly people who are already suffering low or none-existent social interaction, might become even lonelier with the use of these technologies. For many elderly people, the interaction with their nurse or a visit of a caregiver can often be the main interaction with the outside world. When replacing this with an assistive robot, they could become even more socially isolated (Zwijsen et al. 2011b: 423).

It has also been speculated that the implementation of assistive robots to healthcare institutions could decrease the issue of caregivers or nurses mistreating the elderly (Sharkey and Sharkey 2010b: 30).

8 Main limitations of Assistive Robots

One considerable issue in the development of robotics is the missing standardization in the industry in terms of technical language and parameters to follow. Harmonized standards could help to reduce the production cost and to reduce the time to market of these new technologies (SPARC 2016b: 312). Standards give the users the security that the products are developed properly, and that they are compliant and safe. From the business point of view, standardizing the industry would lead to an easier marketability of the products internationally speaking, e.g. following EU defined standards of production would guarantee for a product to be sold in all of the countries belonging to the union (Finnish Standards Association n.d.).

Due to the missing harmonized vocabulary, the categorization of various assistive robots is unclear and confusing. Having a unified vocabulary is an important part in the legal standardization process of the robotics industry. Despite each country having their own particularities in their definitions, there should be a clear terminology accepted at a global scale that would distinguish different robots and their possible interactions (SPARC 2016c: 312).

International standardization of terminologies, safety measures, boundaries and human-robot interactions among many others, are of particular relevance when propitiating a fast development in the robotics industry. These aspects would need to cover issues related to robots in general as well as to be more specific into each of the different categories; it would be of great importance to have a clear definition of parameters related to human-robot interactions and complex processes such as data protection for the robots destined to the assistive and the healthcare fields (SPARC 2016d: 307).

Currently, there are not many assistive robots on the market that are available for private users. Most of the robots that can be bought by individual consumers are closed platforms that do not allow the integration of additional software or applications. Robots that are under development in laboratories have more advanced functions, but at the same time are too complex for users and not cost effective to mass produce them (Vänni 2018a: 11).

The perception and the acceptance of new technologies by the elderly have been seen as possible issues that could challenge the integration of the assistive robots into their routines. Elderly people are not as keen as the younger on learning how to use new devices (Goher, Mansouri and Fadlallah 2017b: 2). Factors like age, cultural background and education among other demographics, could mark a difference in the willingness of the user to interact with the machine. Regarding the design of the assistive robots, it has been criticized that many engineers, researchers and designers, do not take these matters into account (Flandorfer 2012: 4-8).

The available assistive robots for the general public can be considered too expensive, an issue that has been pointed out as significant limitation for these technologies. How the issue with the prices is handled could influence the rhythm of the market adoption of these products. It is worth noticing that in some regions in Europe elderly people are at a higher risk of poverty and social exclusion.

Based on the Eurostat studies in 2017 18,1% of the EU28 on average were at the risk of poverty, while within that figure there is significant variation in some countries, such as Bulgaria (48,1%), Latvia (43,9%), Romania (33,2%), Croatia (32,7%) and Cyprus

(24,6%). As the provision of health and social care services might suffer in the future due to the probable lack of personnel, these groups might have a higher impact to their wellbeing and accessibility to healthcare services (Eurostat 2018c).

When considering the implementation of assistive robots to the healthcare services, aspects like equal accessibility for everyone should be taken into account. Regardless of the location or social status, all persons should be granted the opportunity to be treated by the development of this technology. Under these circumstances, it should be taken in consideration the affordability of these products and services in order to make it possible (Kritikos 2018c: 16).

Robotic platforms that are intended for elderly users, but currently only available for research purposes, are in a price range that is not affordable for everyone. According to studies, the price of the technology has a considerable impact on the elderly people; they feel that the cost is higher than what they gain from the use of it. Therefore, they would be tending to refuse the integration of the assistive robots (Goher, Mansouri and Fadlallah 2017c: 5).

Among some of the considerable limitations of the assistive robots is the missing ecosystem and available support. Someone who wants to purchase an assistive robot for personal use will face the fact that it is hard to find software either for upgrades or personalized use. Even when finding the right robot, they will not know how to integrate applications to customize the hardware for their use (Vänni 2018b: 11). At the moment there are not enough professionals who are able to provide the technology integration between the users, care facilities and in addition to that offer support for the services (The ROSE Consortium 2017: 30).

9 Conclusion

Since 2008, under the European Commission funded Active Assisted Living Programme, multiple projects have been conducted aiming to develop and implement assistive robots into the daily lives of the elderly (European Commission 2017b: 4). These platforms are designed to help senior citizens to perform tasks that result for them challenging or impossible to do independently. Some of the developed robots can help with more complicated tasks that require physical help like eating, bathing or walking, among many others. Other platforms provide assistance more focused towards the non-physical interactions such as remembering to take medication, connecting with a nurse or registering their health progress.

The studies prove that the implementation of assistive robots would certainly aid the elderly and disabled people in achieving or prolonging their independence, among many other benefits. However, there is still a long way to cover before making it an everyday reality. There are technical, legal, ethical, and socio-economic issues that remain to be solved like: How to integrate these new machines for them to have as much interoperability as possible, boosting their market usability and development and reducing their cost at the same time. How to make affordable and accessible for everyone the service that these technologies would offer? How to approach complex processes related to the data protection that would come from the robot-patient interactions?

Currently, due to the missing standardization on relevant topics for the healthcare and assistive robots' sectors, there are not many commercially available products on the market that could be used by the elderly. In addition to that, there is also missing the necessary maintenance ecosystem that could help users with different issues, such as choosing and setting up the product or providing support when possible malfunctioning would occur (Vänni 2018c: 11).

Another obstacle is the relatively high price for each product unit. There are some concerns when considering the implementation of such technologies in the healthcare regarding some EU countries with a higher risk of poverty among their senior citizens, like Bulgaria (48.9,1%), Latvia (43,9%), Romania (33,2%), Croatia (32,7%) and Cyprus (24,6%) (Eurostat 2018d).

The debates about the ethical issues that concern the use of assistive technologies indicate that a solid legal framework has to be in place before these products can be brought to market, to protect the users from a possible harm, especially those in the minority group (Kritikos 2018d: 16). Hypotheses about how accurate the delimitation of a patient's supervision time can be and his or her private time are still to be furtherly discussed. There is also the need to address the very sensitive issue of software security; what would the repercussions of a robot being hacked be? Despite the challenges that the development of assistive robots faces today, studies show that we are in need of finding a way of assisting the ageing population, and in the near future, these technologies can represent a good solution for it. Topics that could be further investigated on this issue include how to approach the product development in such a manner that it could become financially feasible for everyone? How to bring the assistive robots to the market and how to integrate them into the healthcare in a way that as many elderly citizens could benefit from their use?

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