Robotics4EU

Boosting Wider Adoption of Robotics in Europe

Responsible Robotics & Non Tech Barriers To Healthcare Robotics

Contributors: Öznur Karakaş, Roger A. Søraa, Margaret Ottesen

www.robotics4eu.eu
info@robotics4eu.eu

PARTNERS

CE | ROBOTEX | LOBA | LNE | DBT | AFL | NTNU

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101017283

Table of Abbreviations and Acronyms

Abbreviation	Abbreviation
SAR	Socially assistive robot
MIS	Minimally invasive surgery
IEC	International Electrotechnical Commission
HIPAA	Health Insurance Portability and Accountability Act
OSHA	Occupational Safety and Health Administration
GDPR	General Data Protection Law

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101017283

Index of Contents

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101017283

1. Introduction

This report serves as an introduction to responsible robotics for Healthcare readers. It does so by explaining the current state-of-play of robotics in Healthcare, including an overview of how current issues relate to the development of socially acceptable robots in Healthcare, and gives references to resources relevant to the responsible robotics community.

This document thereby presents the main findings drawn from research and stakeholder engagement activities (desktop research, co-creation workshops, etc.) conducted among robotics community members and policymakers during the Horizon Europe funded Coordination and Support Action project Robotics4EU (2021-2024)[1]. The main objective of the mentioned activities was to gain insight into the main issues in the deployment of robotics, including the current practices, shortcomings and the needs and readiness of the stakeholders as of 2023, but also on the resources available in support of building responsible robots.

More specifically, the focus of Robotics4EU is on the development of responsible robots and the social acceptance of robots in Healthcare, Agri-food, Inspection & Maintenance, and Agile Production. Below is the report on Healthcare which introduces the state of play in the sector, relevant resources, and outcomes of Robotics4EU activities in this particular sector.

1.1. About Robotics4EU

The Robotics4EU (2021-2024) project aims to ensure a more widespread adoption of (AI-based) robots in healthcare, agri-food, inspection and maintenance of infrastructure, and agile production. This goal is reached through the implementation of the responsible robotics principles among the robotics community that results in societal acceptance of the robotics solutions in all application areas.

Robotics4EU will create and empower the EU-wide responsible robotics community representing robotics innovators from companies and academia in the mentioned fields, but also citizens/users and policy/decision makers by rising awareness about non-technological aspects of robotics (ethics, legal, socioeconomic, data, privacy, gender), organising community building and co-creation events that bring together the robotics community and citizens, advocating for responsible robotics among all stakeholder groups, developing a responsible robotics maturity assessment model (a compass for responsible robots) and bringing the project results to relevant standardization bodies.

Robotics4EU will implement the following set of activities:

1. assessing the needs and developing a responsible robotics maturity assessment model that is a practical tool for the robotics developers and helps them to strategically plan and the uptake of the legal, societal and ethical aspects of robotics;

[1] Principles of GDPR were followed throughout the tasks completed to reach the objectives of this deliverable.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101017283

1. empowering the robotics community by organising capacity building events in healthcare, agri-food, agile production and infrastructure;
2. ensuring citizen acceptance of robotics (via citizen consultations) and assessing robotics ideas and applications provided by the industry with end-users (via online consultation and co-creation workshops);
3. reaching out to the policy makers by compiling a responsible robotics advocacy report, organising a high-level policy debate and transferring the results to the standardization bodies.[2]

1.2. Responsible Robotics

In the context of the Robotics4EU project, responsible robotics refers to robots that consider the values and expectations of the society that needs them. This concept plays an important role in Robotics4EU as safer, more considerate, durable, affordable, and practical robotics solutions – responsible robots – will be the central component in avoiding, limiting, and/or removing non-tech barriers that are currently in the way of the widespread adoption of robots.

The project employs various methods to promote responsible robotics in different fields of robotics, including but not limited to: citizen involvement in robotics development, policy recommendations & advocacy plans, and also the creation of a maturity assessment model named Responsible Robotics Compass (RoboCompass).

This Responsible Robotics Compass developed by Robotics4EU will help to assess and determine the maturity of non-technological aspects of a robot in development, regardless of its area of application. It focuses on Legal, Data, Socioeconomic, Human experience, and Sustainability markers, considering how the technology is developed, which internal and external processes are in place, how it interacts with its user, and other relevant risks and risk mitigation measures.

It is a tool that helps companies to 1) identify their level of development along Legal, Data, Socioeconomic, Human experience, and Sustainability dimensions by assessing risks and mitigation steps, 2) receive recommendations and tools on how to improve, 3) track their progress over time. This ensures trust and societal acceptance – all of which are expected to safely and widely adopt robots among its intended users.

In support of developing the Responsible Robotics Compass – the maturity assessment tool in discussion – Robotics4EU executed a wide range of research and engagement activities (incl. stakeholder needs' analysis, interviews, surveys, co-creation workshops and policy workshops) to collect information on current issues as well as solutions regarding the socio-economic, ethical, data, privacy, and legal matters from policy makers and the robotics community (both the producers & consumers).

These insights are gathered into four area-specific introductive reports such as the one at hand that present the State of Play as of 2023, including trends and benefits within the

[2]Project information from CORDIS: https://cordis.europa.eu/project/id/101017283

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101017283

area; describe the Common Non-technological Challenges and Barriers, including issues and worries related to socio-economics, ethics, privacy and legal matters; (3) and highlight Relevant Guidelines, Resources and Initiatives currently available to the robotics community.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101017283

2. State of Play within Healthcare Robotics

This report functions as an introductory guide to responsible robotics for Healthcare readers. It does so by elucidating the present state of play in Healthcare, offering an overview of how ongoing issues intertwine with the development of socially acceptable robots in the Healthcare domain, along with an exploration of the tools and resources accessible to facilitate this progression.

2.1. Trends

The healthcare sector is one of the most important parts of society, where new technology is being developed, tested, and put into use. With approximately 65 million healthcare workers globally[3], and a projected shortage of 10 million workers by 2030[4], there simply aren't enough qualified individuals to meet the demands of this sector[5], which is facing increasingly difficult challenges. With ageing populations requiring higher resources, more medicine, and growing expertise, the healthcare sector is in dire need of assistance. One potential solution can be found in the form of digital technologies, such as robots. The use of socially assistive robots (SARs) has indeed started to be integrated in various healthcare services, including but not limited to rehabilitation[6], dementia support [7 8], elderly care[9 10] , and mental health care[11]. Surgical robots have also been deployed at a growing rate over the last two decades[12], and robotic pharmacies are deployed in some hospitals and larger healthcare clinics to dispense medication.[13]

Medical robots and **care robots** are indeed specified, by Global Data[14], as today's rising trends in the medical robotics sector. According to the report, the medical robotics market, worth USD 4.7 billion in 2020, is expected to grow at a CAGR of more than 11% during 2020

[3] M. Boniol, T. Kunjumen, T. S. Nair, A. Siyam, J. Campbell, K. Diallo, "The global health workforce stock and distribution in 2020 and 2030: A threat to equity and 'universal' health coverage,", BMJ Global Health, Jun 7(6):e009316. doi: 10.1136/bmjgh-2022-009316, 2022.

[4] World Health Organization, "Health workforce", Official website of the World Health Organization, https://www.who.int/health-topics/health-workforce#tab=tab_1 (Accessed on 06.07.2023) 10.1136/bmjgh-2022-009316, 2022.

[5] C. M. Chew, "Caregiver Shortage Reaches Critical Stage." Provider (Wash. DC), 43, pp. 14-16, 2017.

[6] A. Langer, Ronit Feingold-Polak, Oliver Mueller, Philipp Kellmeyer, Shelly Levy-Tzedek, "Trust in socially assistive robots: Considerations for use in rehabilitation," Neuroscience & Biobehavioral Reviews, 104, pp. 231-239, 2019.

[7] L. Hung, C. Liu, E. Woldum, A. Au-Yeung, A. Berndt, C. Wallsworth, N. Horne, M. Gregorio, J. Mann, H. Chaudhury, "The benefits of and barriers to using a social robot PARO in care settings: A scooping review," BMC Geriatrics 19: 232, 2019.

[8] J. A. Dosso, E. Bandari, A. Malhotra, J. Hoey, F. Michaud, T. J. Prescott, J. M. Robillard, "Towards emotionally aligned social robots for dementia: perspectives of care partners and persons with dementia," Alzhemer's & Dementia, 18(S2): e059261, https://doi.org/10.1002/alz.059261.

[9] R. Bemelmans, R. Gelderblom, G. J. Jonker, L. De Witte, "Socially assistive robots in elderly care: A systematic review into effects and effectiveness," Journal of American Medical Directors Association, Vol 13(2), pp. 114-120, 2012.

[10] C. Di Napoli, G. Ercolano and S. Rossi. "Personalised home-care support for the elderly: A field experience with a social robot at home," User Modelling and User-Adapted Interaction 33: 405-440, 2023.

[11] S. M. Rabbitt, A. E. Kazdin, B. Scassellati, "Integrating socially assistive robotics into mental healthcare interventions: Applications and recommendations for expanded use," Clin. Psychol. Rev. 35, 35-46, 2015.

[12] A. Hughes-Hallett, E. K. Mayer, H. J. Marcus et al., "Quantifying innovation in surgery," Ann Surg., 260(2), pp. 205-211, 2014.

[13] T. T. Lakshmi, P. Keerthi, D. Debarshi, M. B. Niranjan, "Recent trends in the usage of robotics in pharmacy," Indian Journal of Research in Pharmacy and Biotechnology, 2(1), pp. 1038-1043, 2014.

[14] GlobalData, Robotics in Healthcare: Thematic Intelligence, November 03, 2022, https://www.globaldata.com/store/report/robotics-in-healthcare-theme-analysis/.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101017283

and 2030. Within the medical robotics sector, the care robotics segment is expected to grow even faster than surgical robotics.
One ongoing trend in robotics in general, and in healthcare robotics, in particular, is the design of more and more autonomous robots that are capable of actively interacting with their environment. While growing autonomy on the side of robots, thanks to the current developments in AI research, raise questions around this risk of human obsolescence, job losses and depersonalisation of otherwise highly affective healthcare services; recent research rather opts for an approach that tends to rely on AI algorithms to assist, and not to substitute, humans in decision-making roles such as medical doctors. Habuzaa et al., for instance, point towards the risks of relying solely on AI algorithms for diagnostic purposes, as they raise concerns around lack of transparency and narrowed diagnostic questions. They report that the role of AI shall rather be assistive. Robotics, in this scenario, stands out as one of the key areas of healthcare in which the use of AI will have tremendous benefits in areas such as the enhancement of independent living in elderly care, robotics surgery, socially assistive robots (SAR), and robotics assisted rehabilitation.
Below is an overview of the recent trends in robotics in healthcare settings classified under the more general categories of surgical robotics and care robots, the latter including rehabilitation robots, be them assistive or therapy robots.

2.1.1. Surgical Robots

A burgeoning trend in general surgery revolves around the surge in laparoscopic and robotic procedures.[17] This trend has gained such momentum that a plethora of devices and platforms designed for robotic surgery, such as the Vinci Surgical System and the Sensei X Robotic Catheter System, have assimilated into the healthcare system. One compelling rationale underpinning the increasing integration of robotics within surgical practices is their capacity to facilitate less invasive procedures through robot-assisted minimally invasive surgery (RMIS), a feat made achievable by the heightened precision and control they offer.

This potential is exemplified by the Smart Tissue Autonomous Robot (STAR) from Johns Hopkins University. Harnessing the power of AI-based computer vision, when synergized with surgery technology, it has showcased its proficiency in enhancing specific facets of surgery, including intricate tasks like suturing and knot-tying.[18] Remarkably, this robotic system has exhibited superiority over human surgeons in certain procedures, such as animal anastomosis.[19] It's noteworthy that the accomplishments of minimally invasive surgery (MIS) have been documented, underscoring its superiority over open surgery. MIS has been proved to result in reduced blood loss, shorter recovery times, and decreased hospitalisation durations.[20]

[15] F. Yakub, Md. Khudzari, A. Zahran, M. Yasuchika, "Recent trends for practical rehabilitation robotics, current challenges and the future," International Journal of Rehabilitation Research 37(1), pp. 9-21, 2014.

[16] T. Habuzaa, A. N. Navaza, F. Hashima, F. Alnajjara, N. Zakia, M. A. Serhania, Y. Statsenko, "AI applications in robotics, diagnostic image analysis and precision medicine: Current limitations, future trends, guidelines on CAD systems for medicine," Informatics in Medicine Unlocked, 24: 100596, 2021.

[17] B. S. Peters, P. R. Armijo, C. Krause, S. A. Choudhury, S. A. Choudhury, D. Oleynikov, "Review of emerging surgical technology", Surgical Endoscopy 32: 1636-1655, 2018.

[18] E. Henderson, "Smart tissue autonomous robot performs laparoscopic surgery on pig soft tissue without human help", News Medical Life Sciences, 2022, Accessed: 28.08.2023, https://www.news-medical.net/news/20220127/Smart-Tissue-Autonomous-Robot-performs-laparoscopic-surgery-on-pig-soft-tissue-without-human-help.aspx

[19] A. Bohr, K. Memarzadeh, "The rise of artificial intelligence in healthcare applications," Artificial Intelligence in Healthcare, 2020: 25-60.

Advancements have also been made in teleoperation, i.e. the remote surgeries with a robot remotely controlled by a human surgeon. One of the advantages of MIS, especially in times of pandemic, is the mitigation of infection risk between the surgeon and the patient.[21] Yet, the reduction of sensory perception due to the mediation of robots poses a disadvantage, as "robotic control interfaces typically do not provide force or tactile feedback".[22] An ongoing trend in RMIS thus comprises further research on the improvement of haptic feedback. For that purpose, virtual reality (VR) technologies are integrated in robotics surgery for the purpose of training surgeons to improve their skills in operating robotic interfaces.

2.1.2. Care robots

Care robots, or socially assistive robots (SARs), have a number of application areas such as aged care and improving the conditions of children and adults with a number of mental disorders. Personalised affect-aware socially assistive robotics, for instance, has shown potential for augmenting interventions for children with autism spectrum disorders (ASD).[23]

Care robots are primarily developed to assist in tasks such as monitoring and aiding elderly individuals both physically and mentally, or in assisting in the education of children with autism.[24] A systematic review conducted by Leonardsen et al. (2023) investigated the utilisation of robotic technology in the healthcare of individuals above the age of 65. Their findings indicate that robotic technology is mainly utilised as socially assistive companions or engagement facilitators, encouraging users to participate in various activities such as reading, singing, dancing, making phone calls, checking the weather report, and answering quizzes.[25]

Socially assistive robots come in different shapes, sizes, and appearances, ranging from humanoid and animal forms to mascots and non-humanoid designs.[26] An example of a care robot is Pepper, a semi-humanoid social robot featuring a wheeled base, two hands, a touch display on its torso, and a head with two RGB cameras, a depth camera, and a microphone and two speakers.[27]

[20] N. Feizi, M. Tavakoli, R. V. Patel aidnd S. F. Atashar, "Robotics and AI for teleoperation, tele-assessment, and tele-training for surgery in the era of Covid19: Existing challenges, and future vision," Front. Robot AI. 8, pp. 1-9, April 2021.

[21] *idem.*

[22] F. Jourdes, B. Valentin, J. Allard, C. Duriez, B. Seeliger, "Visual haptic feedback for training of robotic suturing," Front. Robot. AI. 9, pp. 1-15, February 2022.

[23] Z. Shi, T. R. Groechel, S. Jain, K. Chima, O. Rudovic, M. J. Matarić, "Toward Personalized Affect-Aware Socially Assistive Robot Tutors for Long-Term Interventions with Children with Autism", ACM Transactions on Human-Robot Interaction 11(4): 1-28, 2018.

[24] M. Kyrarini, F. Lygerakis, A. Rajavenkatanarayanan, C. Sevastopoulos, H. R. Nambiappan, K. K. Chaitanya, A. R. Babu, J. Mathew, and F. Makedon, "A Survey of Robots in Healthcare," Technologies, vol. 9, no. 1, pp. 8, 2021.

[25] A. L. Leonardsen, C. Hardeland, A. K. Helgesen, C. Bååth, L. Del Busso, and V. A. Grøndahl, "The Use of Robotic Technology in the Healthcare of People above the Age of 65-A Systematic Review," Healthcare (Basel), vol. 11, no. 6, Mar 21, 2023.

[26] E. Martínez, F. Escalona, and M. Cazorla, "Socially Assistive Robots for Older Adults and People with Autism: An Overview," Electronics, vol. 9, pp. 367, 02/21, 2020.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101017283

Leonardsen et al. (2023) emphasise that the majority of studies in this field have approached robot technology from a stakeholder perspective. They recommend conducting studies employing longitudinal methods that focus on user perspectives in order to evaluate the effectiveness of the use of robots for elderly individuals compared to traditional care.[28]

Another challenge in this field is testing socially assistive robot technology in real home environments without supervision.[29] Personalization of socially assistive robots, taking into consideration users' personality traits, cognitive states, and the adaptability of the robot to home environments, plays a crucial role in determining the acceptance of this technology by elderly patients.[30] Although this technology is still in its early stages, studies investigating the development and validation of personalised robots have been conducted both with children with autism spectrum disorders and with elderly people living at home.

[27] M. Kyrarini, F. Lygerakis, A. Rajavenkatanarayanan, C. Sevastopoulos, H. R. Nambiappan, K. K. Chaitanya, A. R. Babu, J. Mathew, and F. Makedon, "A Survey of Robots in Healthcare," Technologies, vol. 9, no. 1, pp. 8, 2021.

[28] A. L. Leonardsen, C. Hardeland, A. K. Helgesen, C. Bååth, L. Del Busso, and V. A. Grøndahl, "The Use of Robotic Technology in the Healthcare of People above the Age of 65-A Systematic Review," Healthcare (Basel), vol. 11, no. 6, Mar 21, 2023.

[29] C. Di Napoli, G. Ercolano, and S. Rossi, "Personalized home-care support for the elderly: a field experience with a social robot at home," User Modeling and User-Adapted Interaction, vol. 33, no. 2, pp. 405-440, 2023/04/01, 2023.

[30] idem

[31] Z. Shi, T. R. Groechel, S. Jain, K. Chima, O. Rudovic, M. J. Matarić, "Toward Personalized Affect-Aware Socially Assistive Robot Tutors for Long-Term Interventions with Children with Autism", ACM Transactions on Human-Robot Interaction 11(4): 1-28, 2018.

[32] C. Di Napoli, G. Ercolano, and S. Rossi, "Personalized home-care support for the elderly: a field experience with a social robot at home," User Modeling and User-Adapted Interaction, vol. 33, no. 2, pp. 405-440, 2023/04/01, 2023.

3. Challenges and Barriers for Healthcare Robots

3.1. General limitations to successful market entry and adoption of robots

According to Eurostat (2017), a quarter of European industries uses robots in its operations. Industrial robots are more commonly used than service robots, the latter most frequently used in warehouse management (44%), transportation of people and goods (22%), cleaning and waste disposal (21%), and assembly works (21%). Despite groundbreaking developments in technology, this picture points towards limited adoption of robots even in industrial settings.

Basic limitations to wider adoption of robots include affordability, safety, initial or operational costs related to constant reliance on software programmers, maintenance requirement (the risk of malfunction) and limited flexibility. The high implementation cost of robots is known to be an impediment for especially SMEs.[33] Programming industrial robots, requiring constant supervision of highly skilled employees, on the other hand, remain a challenge to be overcome. This particular challenge has led to Low Code & No Code Programming which aims to simplify the process of teaching robots to undertake a task. In order to avoid the risk of malfunction, leading to safety issues, robots must also be regularly maintained, which is added to the operational cost. Finally, industrial robots mostly have limited mobility, and one of the most important technical limitations to wider adoption of robots is motion planning. Motion planning refers to the process of specifying mobility from a current pose to a desired pose. This is of utmost importance in a time when collaborative robots are being introduced to the market.

Among the non-technologies limitations, fear of job loss/replacement continues to pose a threat to wider uptake of robotics. The research of Sotiris et al. regarding the impact of especially industrial robots on demand for workers of different education, age and gender in 10 high-income countries and 30 industries indeed demonstrates that software and robots reduced the demand for low- and medium-skill workers, the young and women, especially in manufacturing industries, otherwise raising the demand for high skilled workers, older workers and men, especially in service industries.[34]

3.2. Issues specific to Healthcare

Challenges to the social acceptance of robots largely depend on the sector they are designed for. Technology adoption is indeed context-dependent.[35] Yet, existing statistics concerning social acceptance and adoption of robots mostly give an idea merely on industrial robots and

---

[33] J. Williamson, "Robot adoption: The SME challenge," December 2019, Accessed on 25.08.2023), https://www.themanufacturer.com/articles/robot-adoption-the-sme-challenge/.
[34] https://academic.oup.com/economicpolicy/article-abstract/34/100/627/5799078
[35] M. Sostero, "Automation and robots in services: Review of data and taxonomy. European Commission. JRC Working Paper Series on Labour, Education and Technology 2020/14, 2020.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101017283

robots used in transportation.[36] This calls for a sector-based analysis on the obstacles to wider adoption and acceptance robots.

Digital technologies have long been used in healthcare, encompassing various applications such as medical journals, patient care logistics, sensor and monitoring systems, and more. Robots are among the many strategies employed to address healthcare issues and provide quality patient care. However, researchers have pointed out that there is "only fragmented knowledge about the use of robots in healthcare"[37] and implementing robotics in the healthcare sector is particularly challenging.

The findings of a comprehensive survey conducted by Compagna and Kohlbacher[38] on service robots used in care settings indicate that many robots are still in the research phase with low Technology Readiness Level (TRL), and only a few commercially available robots have been deployed in real-life work settings. The high cost of robots was mentioned as the reason for that problem, but the researchers anticipate that healthcare robots will follow a trajectory similar to industrial robots, where increased demand and technological maturity lead to more affordable prices and wider adaptation. Yet, a recent study assessing adoption of interactive robot applications in healthcare at the upper levels of Technology Readiness Level (TRL) reports a gap between technology readiness and adoption levels. Östlund et al. state that "while robots are ready from the technological point of view, most of the applications had a low score for demand according to the stakeholders"[39]. Consequently, the non-adoption of otherwise technologically ready robotics solutions emerges as a problem, which can only be resolved through an analysis of non-technological impediments to their societal acceptance.

Below is a brief analysis on these non-technological impediments under the categories of ethics, socio-economics, data, legal and education & training.

Ethics

There are significant ethical challenges with implementing wider uptake of robots in care settings. Especially, when humanoid robots, and even zoomorphic animal look-alike robots like PARO[40] are involved in care work, questions arise regarding values, morals, and the essence of care itself.

[36] B. Östlund, M. Malvezzi, S. Frennert, M. Funk, J. Gonzalez-Vargas, K. Baur, D. Alimisis, F. Thorsteinsson, A. Alonso-Cepede, G. Fau, F. Haufe, M. Di Pardo and J. C. Moreno. 2023. "Interactive robots for health in Europe: Technology readiness and adoption potential". Front. Public Health 11: 979225, p. 3.

[37] Z. Dolic, R. Castro and A. Moarcas, "Robots in healthcare: A Solution or a problem? European Parliamentary Research Service, 2019, Available online at http://policycommons.net/artifacts/1335161/robots-in-healthcare/1941450.

[38] D. Compagna, F. Kohlbaker, "The limits of participatory technology development: The case of service robots in care facilities for older people," Technological forecasting and social change, Vol. 93(4), pp. 19-31, 2014.

[39] B. Östlund, M. Malvezzi, S. Frennert, M. Funk, J. Gonzalez-Vargas, K. Baur, D. Alimisis, F. Thorsteinsson, A. Alonso-Cepede, G. Fau, F. Haufe, M. Di Pardo and J. C. Moreno. 2023. "Interactive robots for health in Europe: Technology readiness and adoption potential". Front. Public Health 11: 979225, p. 1.

[40] L. Hung, C. Liu, E. Woldum, A. Au-Yeung, A. Berndt, C. Wallsworth, N. Horne, M. Gregorio, J. Mann, H. Chaudhury, "The benefits of and barriers to using a social robot PARO in care settings: A scooping review," BMC Geriatrics 19: 232, 2019.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101017283

Vandemeulebroucke et al.[41] conduct a systematic literature review on the way ethical questions are covered in the literature on aged care. While they classify the ethical approaches into four categories, namely deontological, principalist, objective list, and care-ethical, the ethical issues highlighted by all four approaches typically revolve around preserving human autonomy (be it the aged person's control over the interaction with the robot or the precedence of human care over care provided by robots), dignity and safety. Vandemeulebrouke et al.[42], in their analyses of older adults' perception of SARs in aged care, for instance, point towards concerns around dehumanisation of care practices and lack of autonomy/control over one's life.

Yet, this literature is mostly restricted to aged care and remains fragmented.[43] To bridge this gap, Boada et al. conduct a comprehensive literature review of 56 publications, and encounter a total of 26 highly heterogeneous ethical questions. Among these ethical questions, privacy/data control, deception and autonomy appear the most frequently. Hence, it can aptly be stated that questions around human autonomy remain an important axis for ethical concerns surrounding the use of care robots in healthcare. It can also be further specified that research is required especially on the use of robots in healthcare settings other than aged care.

Socio-economics

The socio-economic barriers to wider adoption of robotics in healthcare involve, first and foremost, afore-mentioned concerns around job replacement and skill depreciation, which would lead to a constant need to upskill and/or reskill the labor force.

Other socio-economic concerns revolve around user profiling and the way user preferences are accounted for in design processes. A study by Iroju and Ikono[44], for instance, highlights several socio-economic obstacles to the social acceptance of robots and the establishment of trust in technology-based care. They point to challenges of homogenous user profiling, emphasising the importance of robots being better matched to user preferences. The lack of diversity thinking among potential end users and the varied responses of different individuals to robots have also been suggested as barriers[45]. This all points to the need for considering varied end-user preferences during the design phase of robots.

[41] T. Vandemeulebroucke, B. D. De Casterle and C. Gastmans, "The use of care robots in aged care: A systematic review of argument-based ethics literature," Archives of Gerontology and Geriatrics 74: 15-25, 2018.

[42] T. Vandemeulebroucke, B. D. De Casterle, L. Walbergen, M. Massart an C. Gastmans, "A focus group study with older aultsin Flaners, Belgium," Journal of Gerontology: Social Sciences 75(9): 1996-2007, 2020.

[43] J. P. Boada, B. R. Maestre and C. T. Genis, "The ethical issues of social assistive robotics: A critical literature review", Technology in Society 67: 101726, 2021.

[44] O. Iroju, O. A. Ojerinde, R. Ikonu, "State of the art: A study of human-robot interaction in healthcare," I. J. Information Engineering and Electronic Business, Vol. 3, pp. 43-55, 2017.

[45] R. A. Søraa, AI for Diversity, CRC Press, 2023.

Data

Issues related to data protection and data privacy are among the most important non-technological issues encountered in the healthcare sector. In the literature, they sometimes overlap, and discussed along with ethical and legal concerns. Data protection appears as a constant concern, especially in settings where a socially assistive robot is used by more than one person. Data privacy is also a concern especially in industry where private companies need measures to protect data of commercial value. Cybersecurity concerns accompany data privacy concerns and pose challenges to successful implementation of robotics solutions.

Legal

Legal and regulatory challenges associated with implementing robots in vulnerable care settings have also been identified.[46] In their assessment of interactive robots with high Technology Readiness Levels (TRL), Östlund et al. (2023)[47] state that social acceptance of robots largely depends on the impact of regulations within the welfare and healthcare sectors in Europe. For instance, the accessibility of new prosthetics, or exoskeletons would largely depend on the insurance schemes of different countries, affecting adoption of early technologies.[48]

In a similar vein, it is also underlined that lack of a common policy that would be applicable for all European countries might pose challenges to the acceptance of robots, given the diversity of healthcare and welfare system across Europe.[49]

The adoption of a new set of regulations at the European level, commonly referred to as the EU AI Act, on June 14, 2023, might put an end to this fragmentation. Yet, it is yet to be studied how the new regulation would impact robotics in different sectors.

Education & Engagement

Lack of access to statistics about social uptake and acceptance of robots, as well as potential areas of use and users beyond manufacturing industry is stated to be a Europe-wide problem that impede wider social acceptance of healthcare robotics.[50] It is therefore highly recommended developing statistics on uptake, sales volumes and use of robots in sectors beyond the manufacturing industry. This requires going beyond consumer markets, and prioritising the specific context of robotics applications in welfare services and procurement of public goods.

[46] E. Fosch-Villaronga, Robots, Healthcare, and the Law: Regulating Automation in Personal Care, London: Routledge, 2019.

[47] B. Östlund, M. Malvezzi, S. Frennert, M. Funk, J. Gonzalez-Vargas, K. Baur, D. Alimisis, F. Thorsteinsson, A. Alonso-Cepede, G. Fau, F. Haufe, M. Di Pardo and J. C. Moreno, "Interactive robots for health in Europe: Technology readiness and adoption potential". Front. Public Health 11: 979225, 2023, p. 1.

[48] M. F. Bauman, D.Frank, L-C Kulla, T. Stieglitz. Obstacles to prosthetic care -Legal and ethical aspects of access to upper and lower limb prosthetics in Germany and the improvement of prosthetic care from a social perspective. Societies 10:10, 2020. doi:10.3390/soc10010010.kilian.

[49] Idem

[50] B. Östlund, M. Malvezzi, S. Frennert, M. Funk, J. Gonzalez-Vargas, K. Baur, D. Alimisis, F. Thorsteinsson, A. Alonso-Cepede, G. Fau, F. Haufe, M. Di Pardo and J. C. Moreno, "Interactive robots for health in Europe: Technology readiness and adoption potential". Front. Public Health 11: 979225, 2023,p. 14-15.

[51] Idem

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101017283

Common Issues within Responsible Robotics

Socio-Economic Analysis	Ethics	Data
• Fear of tech unemployment • Loss of worker autonomy • Rising skill gaps and skill depreciation • Insufficient protection of worker rights (gig-economy) • Lack of diversity thinking • Homogeneous user profiling	• Safety and security at the workplace • Lack of responsibility and accountability • Lack of transparency & liability • Infringements of traditional and cultural norms and values • Gender inequality • Human rights abuse • Preserving human autonomy • Preserving human dignity	• Surveillance issue • Lack of informed consent • Lack of data control and • Vulnerability of cyber physical systems • Cyberwarfare (social & political manipulation)

Legal	Education and Management
• Varied impact of welfare of systems of member countries • Lack of Europe-wide governance • Lack of and lag in regulatory development • Unharmonized regulations (inconsistent set of rules for human-machine cooperation)	• Lack of access to statics regarding sectors other than manufacturing • Insufficient knowledge on robotics in sectors other than manufacturing • Need for sector-specific knowledge production in healthcare

Figure 1. Common issues in the adoption of robotics across areas as identified by the Robotics4EU project

3.3. Findings from Robotics4EU

Researchers affiliated to the Robotics4EU project conducted interviews with robotics experts from a wide range of European countries in agile production, inspection and maintenance of infrastructure, healthcare and agri-food sectors in the spring of 2021. The interview questions **focused on the social acceptance of robots** in these sectors. The duration of the interviews ranged from approximately 30 to 55 minutes.

Researchers affiliated to NTNU also conducted a series of workshops in the fall and spring period of 2022, four digital and one physical, on **the use of healthcare robots in healthcare settings.** In total 252 participants attended the workshops.

The workshops began with one or two keynote speeches by prominent researchers, developers, innovators, and qualified professionals in the area of robotics for healthcare. They were then followed by writing sessions and breakout room discussions centred around the aforementioned five non-technical aspects of robotics integration into healthcare services.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101017283

Another follow-up workshop was organised to conduct a four-step collective qualitative analysis comprised of data revision, data mapping, data sorting and thematic analysis. Data issues and legal issues were combined during the data analysis for healthcare robots, as they mostly overlapped.

Findings of the research indicated that most of the interviewees (9), hailing from both the Northern and Southern European contexts, **expressed the belief that social acceptance of SARs, particularly in the healthcare context, was relatively low in their countries**. The interviewees highlighted varying levels of acceptance for different types of robots and emphasised the sector-specific nature of the social acceptance regarding robotic solutions.

While robotics solutions were generally considered well-accepted in sectors such as manufacturing and agri-food, **healthcare was perceived as a sector with comparatively greater concerns regarding the use of robots in care services.** The fear of human obsolescence and the associated loss of job opportunities remained a pervasive concern impeding broader adoption of robotics solutions across all sectors. However, the healthcare sector presented additional challenges due to the inherent emotional and affective nature of care.

Our interviewees held an **ambiguous attitude** towards this aspect which was also influenced by the type of the robot involved. Half of the interviewees (7) believed that there was more resistance to accept humanoid robots working in healthcare settings. An interviewee from Sweden (SWE1), for instance, expressed the belief that non-humanoid robots had a higher chance of acceptance. This was attributed to concerns about the potential negative impact of humanoid robots on children's body image, and the reproduction of racial and gender inequalities. They stated, "I own a land mower, but I wouldn't want Pepper in my house [...] I don't think these robots [the former] would give my daughter strange ideas about her body or reproduce race and gender inequality- humanoid robots potentially could." The human characteristics of humanoid robots like Pepper or AV1 indeed evoked suspicion, as seen when another interviewee [NOR2] mentioned, "He [AV1] is really good at telling secrets, too."

The resistance to humanoid SARs was also reflected in the findings of Pino et al. [12], which indicate that human-like robots, and androids were the least preferred design solutions among end-users in the context of elderly care. However, one interviewee from Norway [NOR4] also believed that humanoid robots were less intimidating, and therefore more easily adopted by humans compared to non-humanoid ones. Yet, this quality posed challenges in managing expectations, as a humanoid robot would be expected to behave more like a human.

The factors that played a **crucial role in the social acceptance of SARs in healthcare** were as follows, according to their levels of importance: cost effectiveness, age and usability. **Cost effectiveness** was considered the most significant factor in determining the social acceptance of SARs, particularly when deployed in the household. However, the **age of the end-user** was believed to have a negative correlation with their acceptance of SARs. According to an interviewee [ITA4], for instance, senior individuals expressed higher concerns regarding the use of SARs.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101017283

Usability was also recognized as a factor that significantly influenced the social acceptance of SARs. An interviewee [ITA4] emphasised the importance of end-users' real life interaction with the "machine-in-action". Interviewees from both Northern and Southern European contexts (Norway, Portugal, and Italy) highlighted that social acceptance increased with broader use and knowledge of robots. In this context, the relative simplicity and user-friendliness of a robot emerged as significant factors in enhancing the social acceptance of SARs in healthcare practices.

3.3.1. Non-technological vectors towards the social acceptance of SARs

During the structured interviews, the interviewees were asked to choose the most important non-technical vector towards the acceptance of SARs among the categories of data issues, legal issues, ethical issues, education & training and socio-economic.

In the accounts of the interviewees, the category of **data issues ranked first as the most important vector influencing social acceptance of SARs in healthcare.** For half of the interviewees, these issues were the most significant vectors to drive social acceptance. For the purposes of this report, we categorise these issues under the framework of legal issues, as legal issues were primarily discussed by our interviewees in relation to data privacy and protection. **Data protection** emerged as the most significant legal concern expressed by the interviewees, particularly in a context where "large amounts of sensor and personal data" were utilized, and the use of Cloud raised additional legal concerns [NOR4]. One interviewee [ITA1] expressed concern about both governments and companies having access to excessive personal data, especially in situations where a SAR is used by multiple individuals [ITA2]. **Data privacy** was identified as another related issue, with certain interviewees [ITA3, ITA4] reporting that companies were hesitant to share their data due to concerns about industrial espionage. **Cybersecurity** also emerged as a pertinent theme, as hacking could present significant challenges for both institutions and their clients.

Key legal concerns regarding the use of SARs in healthcare

Data protection	Data privacy	Cybersecurity

Socio-economic issues (high cost of SARs, human obsolescence, fear of upskilling among healthcare workers), and ethical issues (machine manipulation, dehumanisation, loss of human autonomy) both ranked second as vectors to drive societal acceptance of robots (5 interviewees deemed either socio-economics or ethics as the most pertinent non-technical vector for societal acceptance of robots).

High cost of SARs and human obsolescence and concerns around upskilling healthcare workers were the primary socio-economic concerns expressed by the interviewees. In this context, human obsolescence is defined as the fear that humans in the healthcare sector may lose job opportunities to robots.

The ethical concerns raised by the interviewees were loss of human autonomy, machine manipulation and dehumanization. Loss of human autonomy mostly referred to the apprehension of becoming dependent on robots in this field. The interviewees generally preferred either hybrid control -semi-autonomy- or full human autonomy as opposed to complete reliance on robots. While one interviewee pointed out that the technology was still in its early stages, and the concept of robots was unfamiliar to many [NOR2], another [SWE1] took issue with the unforeseen impact that humanoid robots in caregiving roles might have on the reproduction of social relations, care structures and power hierarchies. It is important to note that the type of the robot used is once again crucial in understanding the ethical concerns around the use of SARs in healthcare settings. This interviewee referred to introducing a humanoid like Pepper as a caregiver as a "very dangerous minefield" due to its potential to disrupt existing care structures.

Humanoid robots that mimic human affection were indeed met with resistance due to concerns about **the unpredictable nature of human-machine interactions** they would evoke. Another interviewee, for instance, highlighted that the long-term impact of humanoid robot usage on brain structure, and the potential behavioral changes resulting from such interactions were not yet well understood. A related ethical concern, categorized under the theme of machine manipulation, was raised by two of the interviewees. They mentioned the possibility of these robots to imitate human emotions for manipulative purposes. One example was a robot pretending to feel sorry to prevent humans from turning them off.

These ethical concerns were interconnected for some interviewees from Sweden [SWE3, SWE1], who expressed the worry that **commercial interests could overshadow ethical considerations** during the implementation of SARs in different healthcare settings. One of them expressed particular concern that both public and private sector actors were more inclined to prioritize cost-effective labor, while showing indifference towards the ethical concerns arising from the introduction of SARs in the healthcare setting.

Key ethical concerns regarding the use of SARs in healthcare

Loss of human autonomy	Dehumanisation

Key socio-economic concerns regarding the use of SARs in healthcare

High cost of sars	Human obsolescence	Fear of upskilling among healthcare workers

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101017283

Findings from the analysis of the workshops mostly coincided with these findings from the interviews:

Ethics	Legal & Data issues	Socio-economic
• Human control/autonomy • Dehumanization • Preservation of rights for humans and humanoid robots	• Locus of accountability (in cases of discrimination by and/or against robots • Infringement of data protection regulations) • Taxation on robots/granting social rights to robots • Consent • Cybersecurity	• Loss of job opportunities to robots • Skills depreciation • High cost of robots

Figure 2. Main non-technological axes discussed in the healthcare workshops.

Human autonomy, along with concerns about the dehumanisation of care, stood out as the most pertinent ethical considerations for the participants. Human replacement, skills depreciation, and the high cost of robots were again the most pertinent socio-economic concerns. It was observed, once more, that data issues overlapped with legal matters. The workshops placed emphasis on the rights and liabilities of robots as active participants in daily life. This diverges from the prevailing narrative in the literature on ethical concerns around SARs, which mainly focuses on the autonomy, safety, and dignity of humans. It is rather acknowledged that robots might also face discrimination, enjoy rights granted to humans, or even be held legally liable -for instance to pay taxes. This highlights a concern for "caring for robots", considering them as "objects of care".[52] In this context, the need to specify the locus of responsibility in human-machine relations remains significant, while also granting more agency to robots.

[52]B. Lipp, "Caring for robots: How care comes to matter in human-machine interfacing," Social Studies of Science 0(09): 1-26.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101017283

4. Solutions and Resources

4.1. Positive Future Scenarios

Future scenarios will largely depend on the way the newly adopted legal regulations, such as the EU AI Act, are implemented in real-life care settings. The EU AI Act puts great emphasis on securing human supervision and control over AI applications, which also encompass AI-based healthcare robotics. While it addresses the ethical question of preserving human autonomy in human-robot interactions by opting for regulations to secure human supervision, above findings also underline the importance of accounting for diverse and context-based user preferences.

A positive scenario in this setting would be to rely on **context-based analyses of user preferences** in different healthcare settings and countries. Including end-user preferences in design processes through co-creation is key to secure socially accepted technologies.

Achieving **a good balance between deontological legal frameworks and context-specific requirements of different robotics solutions** is a must to achieve responsible uptake of robots in all sectors, not the least healthcare.

4.2. Key Initiatives and Organisations

- **National Center for Advancing Translational Sciences (NCATS)**

NCATS forms part of the National Institutes of Health (NIH). It has initiated the Robotics, Automation, and Advanced Manufacturing (RAAM) program to develop and apply innovative technologies to accelerate the translation of biomedical discoveries into new treatments and cures.[53]

- **European Parliament**

The European Parliament has identified healthcare as one of the key areas for robotics, AI, and digitalization developments within several strategic EU documents. The European Commission has funded the SPARC Robotics initiative, a European public-private partnership (PPP) on robotics, with 700 million euros for 2014-2020. In Horizon 2020, the EU has addressed significant research funding for robotics, including specific funding for healthcare applications.

- **euRobotics**

The euRobotics' Topic Group on Healthcare Robotics aims to facilitate the roadmapping process for robotics in healthcare across Europe. The group brings together experts and Intel is working in collaboration with technology providers and researchers to explore the next generation of robotics solutions in healthcare.

[53] L. D. Riek, "Healthcare robotics," Communications of the ACM, Vol. 60, N11, pp. 68-78. (Accessed on 14.08.2023) https://cacm.acm.org/magazines/2017/11/222171-healthcare-robotics/abstract

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101017283

Intel is working in collaboration with technology providers and researchers to explore the next generation of robotics solutions in healthcare. By providing technology and research support, Intel aims to drive the discovery of new applications for AI and IoT technologies within the field of healthcare.

- **The Health Innovation Plan 2030**

In France, the Health Innovation Plan 2030 has a budget of 7.5 billion euros, aimed at developing new technologies related to strategic devices such as surgical robots, implants and prostheses, digital solutions for mental health, biocompatible and connected medical devices. The French government is also getting ready for AI in healthcare.

- **Fraunhofer Institute for Manufacturing Engineering and Automation (IPA)**

The Fraunhofer IPA is a research organisation that is involved in the development of robotics solutions for healthcare applications. The institute is focused on developing robotic systems that can assist healthcare professionals in tasks such as patient monitoring, rehabilitation, and surgery.

- **The Hospital Future Act**

The Hospital Future Act is a funding initiative that allows German hospitals to speed up digitalization and remain competitive at the global scale. The act is aimed at closing the innovation gap in the German hospital sector and promoting the adoption of digital solutions, including robotics, in healthcare.

4.3. Relevant Regulations

- **Occupational Safety and Health Administration (OSHA)**

While OSHA doesn't have any specific standards for the robotics industry, it provides guidelines for recognizing hazards related to robotics in the workplace.

- **International Electrotechnical Commission (IEC):**

The IEC has published a standard, IEC 80601-2-77, to address the specific performance and safety characteristics of robotically assisted equipment used in surgery. The standard is expected to be adopted in the near future by regulatory authorities in most international medical markets for use in assessing the safety of advanced robotic systems and devices used in surgery.

- **The General Data Protection Regulation (GDPR)**

The GDPR, regulating the use of personal data, is relevant for the robotics industry in healthcare, as AI and robotic systems used in healthcare settings collect personal data. Yet, GDPR only partly regulates AI systems, having rules on processing personal data and protecting data subjects against merely automated decision-making.[54]

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101017283

- **The EU AI Act**

The newly adopted EU AI Act will have great importance for the healthcare sector. This new regulation introduces a risk-based approach to AI systems based on the principles of ethical AI. It foregrounds human supervision over AI systems, and takes measures to protect human autonomy, dignity and safety. The future impact of this regulation on the healthcare robotics system is yet to be studied.

4.4. Relevant Publications

A. Van Wynsberghe, “Healthcare robots: Ethics, design and implementation,” London: Routledge, 2016.

A. Langer, Ronit Feingold-Polak, Oliver Mueller, Philipp Kellmeyer, Shelly Levy-Tzedek, “Trust in socially assistive robots: Considerations for use in rehabilitation,” Neuroscience & Biobehavioral Reviews, 104, pp. 231-239, 2019.

B. Lipp, “Caring for robots: How care comes to matter in human-machine interfacing,” Social Studies of Science 0(0): 1-26.

B. Östlund, M. Malvezzi, S. Frennert, M. Funk, J. Gonzalez-Vargas, K. Baur, D. Alimisis, F. Thorsteinsson, A. Alonso-Cepede, G. Fau, F. Haufe, M. Di Pardo and J. C. Moreno. “Interactive robots for health in Europe: Technology readiness and adoption potential”. Front. Public Health 11: 979225, March 2023.

European Commission,
https://digital-strategy.ec.europa.eu/en/library/ethics-guidelines-trustworthy-ai, 2019.
J. P. Boada, B. R. Maestre and C. T. Genis, “The ethical issues of social assistive robotics: A critical literature review”, Technology in Society 67: 101726, 2021.

J. Jaakola, “Ethics by other means? Care robots trials as ethics-in-practice,” Tecnoscienza: Italian Journal of Science & Technology Studies 11(2): 53-71, 2020.

L. Hung, C. Liu, E. Woldum, A. Au-Yeung, A. Berndt, C. Wallsworth, N. Horne, M. Gregorio, J. Mann, H. Chaudhury, “The benefits of and barriers to using a social robot PARO in care settings: A scooping review,” BMC Geriatrics 19: 232, 2019.

M. Boniol, T. Kunjumen, T. S. Nair, A. Siyam, J. Campbell, K. Diallo, “The global health workforce stock and distribution in 2020 and 2030: A threat to equity and ‘universal’ health coverage,”,BMJ Global Health, Jun 7(6):e009316. doi: 10.1136/bmjgh-2022-009316, 2022.

M. Ebers, V. R. S. Hoch, F. Rosenkranz, H. Ruschemeier and B. Steinrötter, “The European Commission’s proposal for an artificial intelligence act: A critical assessment by members of the Robotics an AI Law Society (RAILS)”, J 4: 589-603, 2021.

M. Pino, M. Boulay, F. Jouen, A. Rigaud, " 'Are we ready for robots that care for us?': Attitudes and opinions of older adults toward socially assistive robots", Front. Aging Neurosci, Sec.Neurocognitive Aging and Behaviour, Vol. 7, 2015. https://doi.org/10.3389/fnagi.2015.00141

D. Compagna, F. Kohlbaker, "The limits of participatory technology development: The case of service robots in care facilities for older people," Technological forecasting and social change, Vol. 93(4), pp. 19-31, 2014.

J. M. Robillard an K. Kabacinska, "Realizing the potential of robotics for aged care through co-creation", Journal of Alzhemier's Disease 76(2): 461-466, 2020.

O. Iroju, O. A. Ojerinde, R. Ikonu, "State of the art: A study of human-robot interaction in healthcare," I. J. Information Engineering and Electronic Business, Vol. 3, pp. 43-55, May 2017.

R. Bemelmans, R. Gelderblom, G. J. Jonker, L. De Witte, "Socially assistive robots in elderly care: A systematic review into effects and effectiveness," Journal of American Medical Directors Association, Vol 13(2), pp. 114-120, 2012.

S. M. Rabbitt, A. E. Kazdin, B. Scassellati, "Integrating socially assistive robotics into mental healthcare interventions: Applications and recommendations for expanded use," Clin. Psychol. Rev. 35, 35-46, 2015.

T. Vandemeulebroucke, B. D. De Casterle and C. Gastmans, "The use of care robots in aged care: A systematic review of argument-based ethics literature," Archives of Gerontology and Geriatrics 74: 15-25, 2018.

T. Vandemeulebroucke, B. D. De Casterle, L. Walbergen, M. Massart an C. Gastmans, "A focus group study with older aultsin Flaners, Belgium," Journal of Gerontology: Social Sciences 75(9): 1996-2007, 2020.

World Health Organization, "Health workforce", Official website of the World Health Organization, https://www.who.int/health-topics/health-workforce#tab=tab_1.

Z. Dolic, R. Castro and A. Moarcas, "Robots in healthcare: A solution or a problem? European Parliamentary Research Service, Available online at: http://policycommons.net/artifacts/1335161/robots-in-healthcare/1941459.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101017283

5. Conclusions

This report presents a general overview concerning the use of robotics solutions in healthcare settings. The results point towards the need to integrate analyses on social acceptance and uptake of robots in healthcare settings with analyses on non-technical vectors, especially ethical and legal ones, towards wider adoption of SARs in healthcare.

The findings highlight the importance of conducting further and more nuanced studies to **examine the impact of different design solutions on the social acceptance of SARs**. While it is widely recognized that "SARs cover a wide range of design solutions", including machine-like robots, human-like robots, androids, mechanical human-like robots, animal-like robots[55] and mechanical animal-like robots, the results of the aforementioned Robotics4EU activities emphasise the necessity of identifying the social acceptance of each specific type in particular care settings.

Moreover, they also underscore certain non-technical obstacles associated with the introduction of SARs in healthcare settings. The primary ethical concerns involve apprehensions about the **potential loss of autonomy for humans**. On the other hand, the legal concerns primarily revolve around issues of data privacy, data protection and cybersecurity. This resonates with the findings of both Boada et al.[56] and Robillard and Kabacinska[57] who identify concerns about personal privacy as the most pressing ethical issue regarding robotic technology in healthcare. These concerns also serve as critical barriers to technology adoption.[58]

Both ethical and legal concerns appear to revolve around the **need to specify the locus of accountability** and determine who should be held accountable in human-robot interactions within legal frameworks. Doing so would also prove beneficial in addressing concerns over loss of human autonomy and machine manipulation. Consequently, in an environment where legal regulations lag behind the adept use of technology, particularly by new generations, **ensuring safety and conducting risk assessment**, along with establishing clear guidelines for assigning accountability in cases of malpractice emerge as crucial measures for addressing these challenges.

[55] M. Pino, M. Boulay, F. Jouen, A. Rigaud, " 'Are we ready for robots that care for us?': Attitudes and opinions of older adults toward socially assistive robots", Front. Aging Neurosci, Sec.Neurocognitive Aging and Behaviour, Vol. 7, 2015. https://doi.org/10.3389/fnagi.2015.00141

[56] J. P. Boada, B. R. Maestre and C. T. Genis, "The ethical issues of social assistive robotics: A critical literature review", Technology in Society 67: 101726, 2021 https://doi.org/10.3389/fnagi.2015.00141

[57] J. M. Robillard an K. Kabacinska, "Realizing the potential of robotics for aged care through co-creation", Journal of Alzhemier's Disease 76(2): 461-466, 2020.

[58] ibid.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101017283

The ethical guidelines specified by the European Commission (2019)[59] address most of these concerns, especially concerns around human autonomy, harm prevention and privacy. The proposed EU AI Act also makes emphasis on preserving human autonomy, privacy, and dignity in interactions with AI.[60] However, researchers have also raised concerns about such deontological ethnical guidelines, which are claimed to fall short in addressing the complexities of highly context-specific real-life care settings[61] [62] .

Iroju and Ikono[63], among others, emphasise the importance of context-specificity and the necessity for robots to better align with varied user preferences. The **need to embrace diversity** in thinking when envisaging potential end users during the design phase, as well as the significance of considering the varied responses of different individuals to robots, has indeed been highlighted [64]]. Further research is required to **analyse the implementation of new regulations, and how they are translated in real-life settings.**

[59] European Commission, https://digital-strategy.ec.europa.eu/en/library/ethics-guidelines-trustworthy-ai, 2019.

[60] M. Ebers, V. R. S. Hoch, F. Rosenkranz, H. Ruschemeier and B. Steinrötter, "The European Commission's proposal for an artificial intelligence act: A critical assessment by members of the Robotics an AI Law Society (RAILS)", J 4: 589-603, 2021.

[61] J. Jaakola, "Ethics by other means? Care robots trials as ethics-in-practice," Tecnoscienza: Italian Journal of Science & Technology Studies 11(2): 53-71, 2020.

[62] T. Vandemeulebroucke, B. D. De Casterle, L. Walbergen, M. Massart and C. Gastmans, "A focus group study with older aultsin Flaners, Belgium," Journal of Gerontology: Social Sciences 75(9): 1996-2007, 2020.

[63] O. Iroju, O. A. Ojerinde, R. Ikonu, "State of the art: A study of human-robot interaction in healthcare," I. J. Information Engineering and Electronic Business, Vol. 3, pp. 43-55, 2017.

[64] R. A. Søraa, AI for Diversity, CRC Press, 2023.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101017283

consortium

CIVITTA

robotex International

LOBA®

LABORATOIRE NATIONAL DE MÉTROLOGIE ET D'ESSAIS LNE

Fonden TEKNOLOGIRÅDET

AgriFood DIH Lithuania

NTNU Norwegian University of Science and Technology

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101017283

Robotics4eu

@robotics4eu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101017283