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Trends in Assistive Technologies

Edited by Alejandro Rafael Garcia-Ramirez

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Aims and Scope of the Series

Biomedical Engineering is one of the fastest-growing interdisciplinary branches of science and industry. The combination of electronics and computer science with biology and medicine has improved patient diagnosis, reduced rehabilitation time, and helped to facilitate a better quality of life. Nowadays, all medical imaging devices, medical instruments, or new laboratory techniques result from the cooperation of specialists in various fields. The series of Biomedical Engineering books covers such areas of knowledge as chemistry, physics, electronics, medicine, and biology. This series is intended for doctors, engineers, and scientists involved in biomedical engineering or those wanting to start working in this field.

Meet the Series Editor

Robert Koprowski, MD (1997), Ph.D. (2003), Habilitation (2015), is an employee of the University of Silesia, Poland, Institute of Computer Science, Department of Biomedical Computer Systems. For 20 years, he has studied the analysis and processing of biomedical images, emphasizing the full automation of measurement for a large inter-individual variability of patients. Dr. Koprowski has authored more than a hundred research papers with dozens in impact factor (IF) journals and has authored or co-authored six books. Additionally, he is the author of several national and international patents in the field of biomedical devices and imaging. Since 2011, he has been a reviewer of grants and projects (including EU projects) in biomedical engineering.

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Preface

This book examines recent developments in assistive technology and explores new trends in this rapidly evolving and multidisciplinary field. Assistive technology has gained prominence in recent years due to several factors. One of them is the aging population, which has increased the demand for technologies that help elderly people remain independent and communicate better [1]. Assistive technologies have also been increasingly used by people with physical, sensory, or cognitive disabilities, allowing them to perform daily tasks and participate more fully in society [2]. Another important factor is technological advancement, which has made it possible to create increasingly sophisticated and accessible devices and solutions to enhance independence [3].

Assistive technologies (AT) refer to devices, software, or equipment designed to support people with disabilities. Assistive technologies can be used to support individuals with physical, sensory, cognitive, or developmental disabilities in their daily activities, and can be customized to meet their specific needs and abilities [2]. AT can range from simple solutions such as wheelchair ramps, hearing aids and closed captioning, for example, to more advanced equipment such as speech recognition software, high-tech alternative communication aids, prostheses, voice-activated virtual assistants, and smart wearables, among others.

Assistive technologies are amazingly important for individuals with disabilities, as they enable greater independence, autonomy, and participation in daily life. By promoting accessibility and inclusivity, assistive technologies benefit not only individuals with disabilities but also the broader community [4]. The ability to participate in activities and roles makes an important contribution to people's sense of well-being, social connectedness, and quality of life. Overall, assistive technologies can help people with disabilities to remove barriers to full engagement in society.

Assistive technology also has a significant economic impact, as it can reduce dependence on caregivers and healthcare professionals, increase opportunities for employment and education, and contribute to the inclusion and equal opportunities of people with disabilities or functional limitations [5]. For these reasons, assistive technology is an important area of research and development that has the potential to transform the lives of millions of people around the world.

This collection consists of five chapters. Chapter 1, entitled "Introductory Chapter: Trends in Assistive Technology", discusses the relevance, purpose, trends, and challenges of assistive technology. As assistive technologies become more advanced, there is a potential for greater integration with mainstream technology, allowing individuals with disabilities to use the same technologies as everyone else.

Chapter 2, entitled "Perspective Chapter: Service Robots in Healthcare Settings", looks at several applications of healthcare-oriented robots in acute, ambulatory, and at-home settings. In addition, it describes critical problems for the future when such technology will be ubiquitous.

Chapter 3, entitled "Understanding the Assistive Potential of Consumer Technologies: A Case Example of Smartphones, Smart Speakers, and Internet of Things Technologies", examines the assistive potential of a range of consumer digital technologies and explores how they can benefit people with disabilities and older people. Issues pertaining to risks to personal information, autonomy and consent while using these technologies are also outlined.

In Chapter 4, entitled "Perspective Chapter: Vocational Rehabilitation, Information, Communication Technology, and Assistive Technology Devices for Employment", the authors present a literature review analyzing the present and future of information and communications technology and assistive technology devices in the field of vocational rehabilitation in Japan.

Chapter 5, entitled "Perspective Chapter: Assistive Technology Ecosystem for Effective Self-Care – Application to Alzheimer's and Related Dementia", approaches the challenges of self-care and assistive living, including equitable access to assistive technology and care, the right to choose where to live, protection of privacy and security in people who live with Alzheimer's disease and related dementias. It presents an assistive technology ecosystem that enables autonomy, independence, and interdependence in these complex cases.

Thank you for your interest in this book. It is our hope that the content within these pages will provide you with valuable insights and information that can help you in your personal or professional life. We appreciate your time and attention, and we invite you to continue reading to discover the ideas and concepts that we have compiled to present in this book. We believe that you will find the chapters informative, engaging, and thought-provoking. Thank you again for choosing to read this book, and we hope that it exceeds your expectations.

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References

[1] Yusif S, Soar J, Hafeez-Baig A. Older people, assistive technologies, and the barriers to adoption: A systematic review. International Journal of Medical Informatics. Oct 2016;**94**:112-116. DOI: 10.1016/j.ijmedinf.2016.07.004. Epub 2016 Jul 7. PMID: 27573318

[2] Albert M. Cook, Janice Miller Polgar, Pedro Encarnação. Assistive Technologies: Principles and Practice. 5th Edition - November 8, 2019. eBook ISBN: 9780323523370. Hardcover ISBN: 9780323523387

[3] Agree EM. The potential for technology to enhance independence for those aging with a disability. Disability and Health Journal. Jan 2014;7(1 Suppl): S33-S39. DOI: 10.1016/j.dhjo.2013.09.004. Epub 2013 Oct 7. PMID: 24456682; PMCID: PMC4154228

[4] Marion Hersh, Marcelo G. Gomes Ferreira, Alejandro R. Garcia-Ramirez. In: Garcia-Ramirez AR, Marcelo G, Ferreira G, editors. Introductory Chapter: The Role of Assistive Technologies in Smart Cities. InTech; 2018. p. 1-3. DOI: 10.5772/intechopen.81820

[5] World Health Organization (WHO). Assistive Technology. 2018. Available from: https://www.who.int/news-room/fact-sheets/detail/assistive-technology [Accessed: 08 March 2023]

Chapter 1

Introductory Chapter: Trends in Assistive Technology

Alejandro Rafael Garcia Ramirez

1. Introduction

People may present at any age some type of disability, lack or deficiency of one or more abilities that affects their performance in carrying out tasks appropriate to their level of development, such as walking, speaking, hearing, seeing, among others. Disability is a term used to refer to any physical, sensory, cognitive, or intellectual impairment that significantly affects a person's ability to perform daily activities or participate in society on an equal basis with others [1]. It is a broad and complex concept that comprises a wide range of conditions and limitations, temporary and permanent, and can result from various factors, like genetics, illness, injury, and environmental factors. The definition of disability may vary depending on the context, cultural beliefs, and legal frameworks in different societies [1].

Disabled individuals are prevalent within most extended families, and it is common for non-disabled individuals to provide support and care for their disabled loved ones. As a result, throughout human history, societies have grappled with the ethical and political dilemma of how to effectively incorporate and assist individuals with disabilities. The distress of people with some kind of disability depends more on the environment in which they are inserted than necessarily on the problem they have. The World Report on Disability, jointly produced by the World Health Organization (WHO) and the World Bank, suggests that more than one billion people worldwide suffer from disabilities and reports that people with disabilities generally have poorer health, lower educational attainment, fewer economic opportunities, and higher poverty rates than people without disabilities [2]. This can be attributed in large part to the insufficient availability of services and the numerous obstacles that individuals with disabilities encounter daily. In this scenario, assistive technology (AT) emerges.

Assistive technologies (AT) are devices, tools, and services that help individuals with disabilities to perform everyday tasks and participate fully in society. The goal of AT is to provide support and facilitate independence, while also improving the quality of life for those who use it [3]. As technology continues to advance, so do the possibilities for assistive technologies. In recent years, we have seen a rapid increase in the development and use of new AT devices and services that have the potential to transform the way we assist and support individuals with disabilities. This chapter introduces the new trends in assistive technologies, their benefits, and the challenges that come with them.

1.1 Definition of assistive technology

Assistive technology refers to devices, software, or equipment designed to support people with disabilities, enabling them to participate in various activities and improve their overall quality of life [3]. AT solutions can range from a simple white cane to a complex computerized system controlled by gaze or bioelectric signals. Included in the range of items that can enhance the quality of life for people with disabilities are adapted toys and clothing, computers with special software and hardware that meet accessibility requirements, alternative communication devices, special keys, and triggers, assisted listening devices, visual aids, prosthetic materials, and countless other products.

1.2 Purpose of assistive technologies

The primary aim of assistive technologies is to empower individuals with disabilities to achieve independence, autonomy, and participation in society. AT seeks to enable individuals to overcome the various barriers that they may encounter in their daily lives, such as mobility limitations, sensory impairments, lack of information, or challenges in processing information. Assistive technologies can aid people with disabilities in multiple ways, including improving communication abilities, facilitating access to education and information, performing daily tasks, and participating in the labor force. Furthermore, they can help individuals achieve greater social inclusion, develop their skills, and improve their overall quality of life. Assistive technologies can also generate broader societal benefits, such as promoting diversity and inclusion, reducing healthcare expenditures, and enhancing productivity and economic outcomes [4].

1.3 Relevance of assistive technologies

Assistive technologies are incredibly important for people with disabilities because they provide a means of overcoming barriers and promoting independence, autonomy, and participation. Assistive technologies make it possible for people with disabilities to access and interact with various environments, such as workplaces, schools, public spaces, and the Internet. This sort of technologies enables people with disabilities to perform tasks and activities independently, such as mobility aids that help people to move around and prosthetic limbs that allow people to engage in activities such as sports and recreation [3].

Assistive technologies have the potential to enhance the quality of life for people with disabilities by assisting their engagement in social activities, accessing education and information, and completing daily living tasks. Inclusion is crucial, and assistive technologies can promote diversity and inclusion by enabling individuals with disabilities to fully participate in society and be recognized for their unique skills and perspectives. They can also lessen the economic impact of disability by supporting individuals to enter the workforce, increasing their earning potential, and decreasing their dependence on social welfare programs. All in all, assistive technologies are essential for protecting the rights and well-being of people with disabilities and advancing the goal of building a more equitable and inclusive society [4].

2. New trends in assistive technologies

In this section are described emerging trends in the field of assistive technologies (AT) that have the potential to revolutionary transform the lives of people with disabilities.

2.1 Artificial intelligence

AI has the potential to transform the field of assistive technology by empowering individuals with disabilities to live more independently and actively participate in society. Examples of AI-powered assistive technology is the integration of voice assistants such as Amazon Alexa, Google Assistant, and Apple Siri, which enable individuals with disabilities to manage their home environment, make phone calls, send messages, and access information, among other functionalities [5]. Another example is the Oura Ring that has sensors to capture biological signals and provides reports on the user's health [6]. Personalized assistive technology is also a field of application for AI, where AI-powered prosthetics can learn and adapt to an individual's movements and preferences [7].

The potential of AI-powered assistive technologies is vast, and as technology continues to progress, we can expect to witness more innovative uses of AI in assistive technology. The UN Convention on the Rights of Persons with Disabilities, held in June 2019, recognized that AI "has the potential to enhance inclusion, participation, and independence for people with disabilities" [8]. Numerous organizations are exploring the uses of AI in assistive technologies as a means of improving accessibility. Among them are AI-based visual aids, smarter glasses, cognitive hearing aids, new opportunities for education, and equal opportunities for employment.

2.2 Wearable devices

The use of wearables, such as smartwatches, fitness trackers, and other body-worn devices, has been on the rise in recent years as assistive technology for individuals with disabilities or other specific requirements. These devices offer numerous advantages, including health monitoring capabilities that can track vital signs like heart rate, blood pressure, and oxygen levels, which can be especially beneficial for those with chronic conditions or disabilities [6, 9]. Wearables can also aid communication for people with hearing or speech impairments by pairing with a smartphone app that converts speech to text or vice versa, allowing for more effortless communication [10]. Additionally, wearables can facilitate navigation for people with visual impairments, where smart glasses come equipped with built-in cameras and software that can recognize objects and provide audio feedback to help users navigate their surroundings [11].

Furthermore, wearables can enhance safety for people with disabilities, where some smartwatches offer emergency features that enable users to call for help or share their location in case of an emergency [12].

Wearables possess immense potential to deliver significant benefits for individuals with disabilities or other specific needs. As technology continues to progress, we can anticipate more groundbreaking applications of wearables as assistive technology devices.

2.3 Robotics

Robotics has emerged as a promising technology for assisting people with disabilities in performing daily tasks, achieving greater independence, and improving their quality of life. Robotic assistive technologies can be customized to meet individual needs and can provide support for a wide ranging of disabilities, including mobility impairments, sensory impairments, and cognitive impairments [13].

Robotics can be used to create prosthetic limbs that are controlled by the user's myoelectric signals, enabling greater mobility and independence [7]. Exoskeletons are wearable robotic devices that can help people with mobility impairments walk or stand. They are particularly useful for people with spinal cord injuries or other conditions that affect their ability to move [14]. Robots can be used to assist with a range of everyday tasks, such as cooking, cleaning, and personal care. These robots can help people with disabilities or older adults live independently in their own homes [15].

2.4 Internet of things (IoT)

The field of assistive technology stands to be revolutionized by the potential of the Internet of things (IoT), which allows devices to communicate with each other and gather data in real time. IoT refers to a connected network of devices that can exchange information and perform tasks without human intervention. For instance, IoT sensors can detect falls and automatically alert caregivers or emergency services as necessary [16].

Assistive technology can take advantage of IoT to create customized environments for people with disabilities, such as smart homes. Furthermore, IoT can help monitor health indicators, like heart rate and blood pressure, allowing healthcare professionals and caregivers to provide more personalized and targeted care to individuals with disabilities [17].

Another example of the use of IoT in assistive technology is the development of smart prosthetics. These prosthetics can be connected to the Internet and other devices, enabling users to control them through their smartphones and receive feedback on their movements and other data [18].

IoT can also be used to create more efficient and effective transportation systems for individuals with disabilities. Connected vehicles can be equipped with sensors and other technologies to provide real-time traffic updates, monitor road conditions, and optimize routes to ensure that individuals with disabilities can travel safely and efficiently.

In conclusion, the application of IoT in assistive technology can enhance the quality of life for people with disabilities by offering customized and adaptable solutions that cater to their specific requirements.

3. Challenges

Although assistive technology can offer numerous benefits for individuals with disabilities, there exist various challenges and concerns that need to be addressed when designing, implementing, and utilizing assistive technology. One of the primary challenges is ensuring that assistive technology is accessible by people with diverse types of disabilities, considering factors such as vision, hearing, motor skills, and cognitive abilities to maximize its usability by as many people as possible [19].

Additionally, the cost of assistive technology can be a barrier for individuals with disabilities, and it is essential to consider ways to increase affordability and accessibility, such as through government subsidies or insurance coverage. Moreover, assistive technology typically requires customization to meet the specific needs of each user, which can be time-consuming and costly, and may necessitate specialized knowledge and skills [3].

Much assistive technologies require training to be used effectively. It is important to provide adequate support to ensure that users can use the technology effectively and safely [4]. Maintaining and repairing assistive technology is also essential to ensure its proper functioning, and it is essential to have efficient systems in place to provide timely maintenance and repair services. In addition, privacy and security are significant concerns when using assistive technology that collects and stores sensitive personal data. Developers must consider privacy and security issues and implement appropriate measures to safeguard user data. Moreover, ethical considerations need to be addressed when designing and utilizing assistive technology, including ensuring that it respects the autonomy and dignity of the individual user [20].

4. Conclusion

Assistive technology has the potential to transform the lives of people with disabilities. Tendencies in assistive technology provide more personalized, adaptable, and accessible solutions that can enhance their independence, mobility, and quality of life.

The capability for growth and future developments of assistive technologies is significant, as these technologies continue to evolve and become more sophisticated. As technology becomes more advanced, there is a growing potential for greater personalization in assistive technology solutions. This could involve the use of sensors, artificial intelligence, and other technologies to develop more customized solutions that meet the unique needs of each individual user.

Accessibility is a key in the expansion of assistive technologies, and there is an increasing recognition of the need to ensure that these technologies will be accessible to as many people as possible. This may involve developing more affordable solutions, as well as solutions adaptable and customizable to meet the needs of diverse users.

As assistive technologies become more advanced, there is potential for greater integration with mainstream technology, allowing individuals with disabilities to use the same technologies as everyone else. This could involve the development of assistive technologies that can be used with devices such as smartphones and tablets, as well as greater compatibility with existing technologies. For example, assistive technologies could be used to improve accessibility in public spaces or to enhance learning and education for individuals with disabilities using mobile devices.

Collaboration between technology companies, disability organizations, and individuals with disabilities is essential for the development of effective and user-friendly assistive technologies. By working together, these stakeholders can identify areas of need and develop solutions that are truly responsive to the needs of individuals with disabilities.

Overall, the potential for growth and future developments in assistive technologies is remarkable, and there is great potential for these technologies to enhance the lives of people with disabilities in many ways.

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References

[1] Babik I, Gardner ES. Factors affecting the perception of disability: A developmental perspective. Frontiers in Psychology. 21 Jun 2021;**12**:1-26. DOI: 10.3389/fpsyg.2021.702166. PMID: 34234730; PMCID: PMC8255380

[2] World Health Organization (WHO). World report on disability. 2011. Available from: https://www.who.int/teams/noncommunicable-diseases/sensory-functions-disability-and-rehabilitation/world-report-on-disability [Accessed: 2023-03-08]

[3] Cook AM, Polgar JM, Encarnação P. Assistive Technologies: Principles and Practice. 5th Edition. St. Louis: Elsevier; 8 Nov, 2019. eBook ISBN: 9780323523370. Hardcover ISBN: 9780323523387

[4] Hersh M, Gomes Ferreira MG, Garcia-Ramirez AR. In: Garcia-Ramirez AR, Gomes Ferreira MG, editors. Introductory Chapter: The Role of Assistive Technologies in Smart Cities. London, UK, London: InTech; 2018. pp. 1-3. DOI: 10.5772/intechopen.81820

[5] Gonzalez W. Three Ways AI is Improving Assistive Technology. Jersey City: Forbes; 2021. Available from: https://www.forbes.com/ sites/forbesbusinesscouncil/2021/09/21/three-ways-ai-is-improving-assistive technology/?sh=3312a8df419d [Accessed: 2023-03-08]

[6] Oura. 2023. Available from: https://ouraring.com/ [Accessed: 2023-03-08]

[7] Guizzo E. Dean Kamen's "Luke arm" prosthesis receives FDA approval this advanced bionic arm for amputees has been approved for commercialization. In: IEEE Spectrum for the Technology Insider Dean Kamen's "Luke Arm" Prosthesis Receives FDA Approval. New York: IEEE Spectrum; 2014. Available from: https://spectrum.ieee.org/dean-kamen-luke-arm-prosthesis-receives-fda-approval [Accessed: 2023-03-08]

[8] Magic EdTech. How AI is making assistive technologies more powerful. Available from: How AI is making assistive technologies more powerful — by Magic EdTech — MagicBox — Medium. Nov 8, 2019 [Accessed: 2023-03-08]

[9] Alam MM, Hamida EB. Surveying wearable human assistive technology for life and safety critical applications: Standards, challenges and opportunities. Sensors. 2014;**14**:9153-9209. DOI: 10.3390/s140509153

[10] Hey Google. Available from: https://assistant.google.com [Accessed: 2023-03-08]

[11] Envision Glasses. 2022. Available from: https://www.letsenvision.com/glasses [Accessed: 2023-03-08]

[12] Use your Samsung smart watch in an emergency situation. 2023. Available from: Use your Samsung smart watch in an emergency situation [Accessed: 2023-03-08]

[13] Park KH, Bien Z, Lee JJ, Kim BK, Lim JT, Kim JO, et al. Robotic smart house to assist people with movement disabilities. Autonomous Robots. 2007;**22**(2):183-198

[14] Secciani N et al. Wearable robots: An original mechatronic design of a hand exoskeleton for assistive and rehabilitative purposes. Neurorobotics. 2021;**15**:1-15. DOI: 10.3389/fnbot.2021.750385

[15] Hersh M. Overcoming barriers and increasing independence – Service robots for elderly and disabled people. International Journal of Advanced Robotic Systems. 2015;**12**(8):1-33. DOI: 10.5772/59230

[16] Nuñez TO, Ghizoni Teive RC, Garcia-Ramirez AR. In: Habib MK, editor. A Robotics-Based Machine Learning Approach for Fall Detection of People. Cognitive and Adaptive Behaviors. London, UK: InTech; 2022. pp. 1-15. DOI: 10.5772/intechopen.106799

[17] Chapman K, McCartney K. Smart homes for people with restricted mobility. Property Management. 2002;**20**(2):153-166

[18] Nagaraja VH, da Ponte Lopes J, Bergmann JHM. Reimagining prosthetic control: A novel body-powered prosthetic system for simultaneous control and actuation. PRO. 2022;**4**:394-413. DOI: 10.3390/prosthesis4030032

[19] Punchoojit L, Hongwarittorrn N. Usability studies on mobile user interface design patterns: A systematic literature review. In: Mandl T, editor. Advances in Human-Computer Interaction. London: Hindawi; 2017. pp. 1-22. Article ID 6787504. DOI: 10.1155/2017/6787504

[20] Rebello BC, Garcia-Ramirez AR, Heredia-Negron F, Roche-Lima A. A machine learning-based approach to epileptic seizure prediction using electroencephalographic signals. Journal of Engineering Research. 2022;**2**(8):1-9. DOI: 10.22533/at.ed.317282219056

Chapter 2

Perspective Chapter: Service Robots in Healthcare Settings

Rohit Singla and Christopher Nguan

Abstract

Robots will play a part in all aspects of healthcare. The presence of service robots in healthcare demands special attention, whether it is in the automation of menial labour, prescription distribution, or offering comfort. In this chapter, we examine the several applications of healthcare-oriented robots in the acute, ambulatory and at-home settings. We discuss the role of robotics in reducing environmental dangers, as well as at the patient's bedside and in the operating room, in the acute setting. We examine how robotics can protect and scale up healthcare services in the ambulatory setting. Finally, in the at-home scenario, we look at how robots can be employed for both rural/remote healthcare delivery and home-based care. In addition to assessing the current state of robotics at the interface of healthcare delivery, we describe critical problems for the future where such technology will be ubiquitous. Patients, health care workers, institutions, insurance companies, and governments will realize that service robots will deliver significant benefits in the future in terms of leverage and cost savings, while maintaining or improving access, equity, and high-quality health care.

Keywords: Healthcare, acute care, ambulatory care, surgical robotics, at-home robotics

1. Introduction

With the introduction of robots into industrial domains, the exploration of remote controlled, semi-autonomous and fully autonomous surface robots within the field of healthcare is an area of increasing interest. Robotics has been considered across the major verticals of the healthcare continuum of prevention, screening, diagnosis, treatment, and homecare [1]. However, service robots could potentially fill the roles of typical industrial robots in the management of menial or laborious tasks such as supply chain management and logistics, stocking and inventory control, back-end support as well as delivery within the context of patient care. For example, consider delivery of medication or supplies [2]. With the use of robotics such as autonomous vehicle or drone fleets, a routine one-to-one delivery could be simplified; a high priority urgent delivery during acute care events could be made feasible; or broader community-based delivery could be made autonomous for an entire region [2]. Service robots in healthcare can also serve in direct patient interaction roles including as direct assistance to healthcare workers such as nurses, physicians, imaging technicians, and more [3–5]. In a patient-centered view, service robots may serve the role of comfort care or as personal assistance to the patient for mobilization, feeding or activities of daily life [6, 7]. The breadth of applications is vast. This chapter focuses on the application of service robots at the interface of health care delivery, highlighting advances in acute care settings, such as the hospital or surgical settings; in ambulatory settings such as clinics; and in at-home settings where we consider comfort and health. The detailed discussion of supply-chain and logistics-based service robotics are left to other chapters to discuss.

2. Service robots in acute care settings

Acute care refers to the delivery of short-term diagnosis and treatment of a patient for a medical condition. These settings may require an emergency department visits where patients are rapidly assessed and provided with initial treatment, an admission into hospitals whereby patients are overseen by multidisciplinary healthcare workers, a surgical operation including the post-operative recovery, and any number of related services (imaging or laboratory services for example) required to provide optimal diagnosis and treatment.

The first application of robotics in this setting is with regards to environmental hazards. This mimics the notion of industrial robotics to protect workers from workplace hazards. As underscored by the global COVID-19 pandemic, there is heightened interest in the use of robotics to protect valued healthcare workers and patients from dangerous environmental scenarios including preventable infections, ionizing radiation, or combative and violent scenarios. As a key example, the routine care of patients infected with COVID-19 requires significant investment of time and resources on the healthcare delivery system, while continuing to put healthcare workers at risk, and leading to reallocation of resources and cumbersome delivery of patientcare. For two examples of robots created in response to this pandemic, we refer to two companies based in Denmark. First, consider how the nasopharyngeal swab, required for collection of respiratory mucosa to diagnosis COVID-19, inherently places the worker performing the swab at risk. Lifeline Robotics (Odense, Denmark) developed the CAREEBO system, the first of its kind to perform a fully automatic swab analysis [8]. The robotic system is designed to interact with patients and perform the swab itself, obviating the need for a healthcare worker to be in proximity with a potentially infectious individual [8]. Likewise, disinfection and sterilization of the surrounding environment is a key step in the preventing infectious disease transmission. Existing procedures still rely on human staff to perform the cleaning, which may in turn be tedious, costly, and time consuming as well as an avoidable exposure. Towards prevention in hospital settings, ultraviolet light has been utilized in a touchless manner through mobile service robotics. This approach has been demonstrated superior results to manual cleaning when evaluating the number of microbes as well as reducing infection [9]. Commercial offerings exist, such as UVD Robots (Odense, Denmark) designed to disinfect patient wards and operating rooms in between admissions [10].

In a similar fashion, despite standard of care barrier methods, interventional radiologists and radiology technicians who work with and nearby to ionizing radiation continue to suffer increased rates of malignancies as compared to the general population. Mitigating the exposure risk for these individuals directly relates to their safety. Enhanced robotic imaging instrumentation may be the avenue to achieve this. However, to the best of our knowledge, there is not yet a fully autonomous commercial imaging system available for clinical usage. Researchers have explored the notion of a robotic imaging instrumentation. As an example, Haliburton *et al.* towards a service robot for a fluoroscopy machine by demonstrating their tracking system called On-board Position Tracking for Intraoperative X-rays (OPTIX), achieved clinically relevant accuracies through the addition of a single camera [11]. The end goal for OPTIX was to reduce the number of fluoroscopic images required in an operation [11]. This system is one step towards semi-autonomous and fully autonomous robotic systems. Environmental safety, as demonstrated by infection risk and ionizing radiation, can be ameliorated using service robots. In doing so, we consequently mitigated the overhead of anxiety and stress related to working in these potentially hazardous environments.

Moving beyond environment, service robots have a role to play at the patient's bedside. In the most literal example, service robots can assist patients with physical limitations such as reduced physical ability or a bariatric patient in mobility. For these patients, service robots enable patients to have fundamental needs such as having a robotic arm to mitigate the loss of mobility in one's natural arm. Japanese researchers at the RIKEN-TRI Collaboration Center for Human-Interactive Robot Research developed the world's first nursing-care robotic system that can transfer a patient from a bed to wheelchair, and vice versa [12]. However, more generally, service robots enable "contactless" approaches to techniques that would otherwise require an in-person human element. Researchers at Massachusetts Institute of Technology (MIT) repurposed the commercially available Spot™ from Boston Dynamics, a dog-like robot [13]. This robot was modified to include additional cameras, allowing contactless measurement of key vitals such as temperature, blood oxygen saturation and respiratory rate without human intervention. These tele-monitoring style systems may allow for workplace efficiencies as well, reducing undue burden on healthcare staff from frequent monitoring. A relatively easy extension to tele-monitoring is telepresence. Ava Robotics, a spin-off company of consume robotics company iRobot, offers telepresence robotic systems capable of spatially mapping and navigating environment [14]. This type of technology then enables a remotely placed clinician located in a risk-free environment to interact and engage with patients at the comfort of their own beds. This form of telepresence is useful to provide healthcare access from scarce experts, improving upon health inequities.

Service robots are no stranger in surgery. Surgical assistive systems have been present in various applications for several decades now [15]. While surgical care itself spans pre-operative assessments, imaging and planning up to, and including, post-operative recovery, the most abundant example of surgical robotics is in the operating room itself. Medtronic, one of the largest medical technology companies in the world, has offerings of spine and orthopedic systems (MAZOR™) that fully integrate with pre-operative imaging, and allow surgeons to achieve highly precise movements within an accuracy of a few millimeters [16, 17]. Knee and hip replacements have seen significant benefit from robotic systems provided by Mako Surgical [18, 19]. One of the most common surgical robot systems is the da Vinci surgical system™ from Intuitive Surgical (Sunnyvale, USA) [1, 20]. This tele-operated system facilitates surgeons improved workflow and ergonomics, extended degrees of motion, tremor filtering, and enhanced visualizations [1, 20]. In this setup, the surgeon is not directly operating the surgical instruments, but instead is manipulating them in a one-way feedback manner. In more recent offerings of the da Vinci™, integrated table motion allows for additional ambient capabilities to manipulate the surgical environment to the benefit of the surgery at hand [21, 22]. This feature allows the surgeon to leverage gravity assistance to manipulate patient position and internal organs by motion of the operating table, and the simultaneous movement of the robotic arms [21, 22]. The growth of commercially available products in surgical environments has simultaneously spurred an active area of research. Investigators now seek to add additional capabilities to these platforms. Examples of these pre-clinical abilities include task automation ranging from suturing, knot tying, and needle insertion in minimally invasive surgery, autonomous intra-operative ultrasound scanning, and automated camera control and motion as well as telerobotic capabilities [23–28]. However, while the first completely remote surgery was performed in the early 2000s, the ability to use this technology has remained elusive due to challenges in network bandwidth, latency, video communication.

Closely related are service robots in anesthesia which may provide oversight of patient management and procedures. This may include automated drug delivery of adequate anesthetic and analgesic medication through closed-loop control systems for monitoring and administration as well as management of medical devices such as adaptive ventilatory and circulatory support [29–31]. In the pharmaceutical delivery application, robotic systems which receive information directly from the patient by way of a suite of sensors could process such multi-dimensional high-resolution data in a manner human practitioners may be incapable of doing. In turn, there may be benefits to be seen through service robotics which respond in real-time to the patient needs with minimal guesswork required. In terms of circulatory support, the LUCAS robot system acts as an entirely mechanical and automated cardiopulmonary resuscitation device and has been shown to improve outcomes while obviating the need for manual chest compressions from support staff [32]. Beyond these applications, the use of robots to perform needle interventions for regional anesthesia and automatic intubation have been explored [33–35]. However, these systems remain largely pre-clinical in validation, with robust clinical benefit not yet shown.

3. Service robots in ambulatory care settings

While several of the applications (like sanitization, autonomous imaging, or robotic procedures) in acute care may extend into the ambulatory care setting, there are unique applications to consider. When applied to the ambulatory care setting, we consider service robots for the protection as well as empowerment and scaling up of the healthcare workforce.

In a similar fashion to environmental protection, service robots can protect the workforce from self-inflicted pitfalls such as fatigue risk. Chronic shortages of physicians and allied healthcare professionals leads to an overworked workforce, exacerbated by external stressors and cognitive overload, and resulting in a negative impact on attention, reaction, memory, and reasoning [36]. This in turn ultimately leads to inadvertent medical errors made by these well-intentioned individuals. It can also lead to increased psychological distress, insomnia, and depression [37–39]. Service robots in this roll could offload menial tasks and cognitive overhead so that healthcare workers could concentrate on more critical tasks related to direct patient care. In similar fashion, service robots could play the role of validation units in ensuring that health care workers are delivering the intended therapeutic to the patient in the right amount, at the right time, and in the right place. The notion of a robotic assistant has been well received by certain disciplines, such as nursing [40].

Leveraging of the workforce is another potential use of service robots in healthcare. Instead of one-to-one management between health care practitioner and patients, service robots allow for one healthcare practitioner to oversee the care (or subset thereof) for multiple patients simultaneously. This would have implications for health care delivery on a global scale such that fewer workers could provide access to higher quality care to a broader population of patients.

4. Service robots in At-home care settings

In the final section of this chapter, we examine the role of service robots in at-home care settings. In these settings, the patient is often not traveling to another institution to receive care. Instead, they either receive care from external providers in the comfort of their own home or are able self-administer care. In these diverse at-home settings, service robots may play a role in both delivering and providing actual medical care to patients but also in providing companionship and reassurance to those in times of need.

The evident application of robots at home is the use of telepresence. To address geographic disparities in equitable health access, as well as to reduce patient burden such as time and travel expenses, the use of telepresence enables clinicians to serve populations otherwise inaccessible [41]. In the simplest form, telepresence uses video communication apps available on smart devices or computers. However, more advanced immersive versions provide a physical mobile platform, allowing the user to move around the environment. Researchers have sought to automate classical physical examination techniques such as palpation [42] as well as advanced techniques such as ultrasound [42, 43]. While these technologies have not seen widespread integration in telepresence, one recent example is remote medical imaging. Imaging in remote areas is an exciting opportunity, as many communities lack individuals with the expertise to acquire and interpret high-quality images, providing a barrier to care. Clinicians in Saskatchewan, Canada deployed the MELODY system from AdEchoTech in a small study, finding that 92% of organs displayed on conventional examination were seen on those performed remotely, demonstrating the clinical feasibility of such remote imaging [44].

For individuals in rural and remote areas, or in emergent need such as in disaster relief, service robots can facilitate the delivery of medications and supplies. For example, drones themselves can travel fast and without geographical challenges. By leveraging these unnamed transport systems, drones could be used to distribute key medical resources to those in need. This is particularly advantageous in disaster settings whereby conventional transportation is not feasible [45, 46]. In commercial efforts of drone delivery, Zipline (San Francisco, USA) piloted blood distribution via drone delivery in Rwanda [47]. The use of service robotics for aerial transportation of medical resources resulted in a reduced transportation time of 4 hours to approximately 30 minutes [47]. Through coordinated efforts via fleets, drone delivery could extend to become an entire distribution network across entire communities.

Beyond the delivery of care, there is also the role of service robotics for self-care at-home. As exemplified by the COVID-19 pandemic, mental health including anxiety, depression and loneliness have increased significantly in the forefront of the general public's mind. As outbreaks occurred, entire long term care facilities were placed on "lockdown", restricting the movement of its patients and their visitors, for prolonged periods of time. In essence, these actions negatively impacted individuals' need for social interaction, a key component of one's mental health. How then can robots address this need? Through the patient-centered design of social robots designed specifically to assist in the emotional and mental well-being of patients. BUDDY, a companion robot offered by the company of the same name, is one such example [48]. The small mobile esthetically pleasing robot can provide the social interaction needed for elderly patients isolated from others while aiding with activities of daily living and fall detection. Likewise, the use of the PARO robot was demonstrated to provide both social and physical interaction benefits, as well as a potential increase in activity levels, in a cohort of patients with dementia [49]. For children, these robot systems can assist in neurodevelopment and socialization skills. One example is Moxie™ from Embodied, developed in-part by child development experts, for customized learning and play [50].

5. The challenges of service robots in healthcare

While the growth of service robot applications in healthcare is rapid, there are significant barriers to widespread adoption that are worth noting. The first of these challenges is regulation. Unlike consumer technologies, healthcare is heavily regulated with a stringent review process. This inherently causes a longer development process dependent on the scope of functions expected of the robot. As expected, the regulatory approval duration increases with the complexity and risk of these robots. In a medical setting, such as surgery, there is minimal margin for error as the consequences are often grave. This regulation lends itself to the second issue of liability. If a service robot is deployed, who is to blame for when it fails to perform correctly? If used to disinfect a room, and subsequent someone is infected, who at fault? Liability from a legal perspective must be carefully considered, especially as systems become increasingly autonomous. Third is privacy and ethics. To excel at their function, these service robots often require knowledge, or the ability to gather it, about their patient and need to be able to process that knowledge. However, this may require processing of the patient's personally identifying information including voice and face or require transmission of data outside of the robot. The risk of an unwanted intruder accessing such information is non-trivial. How privacy concerns for patients, providers, and insurers are all addressed in robotic settings is an ongoing area of investigation.

The practical deployment of these robots also remains a barrier. While there is promise, significant portions of the core technology – particularly those that require interaction with healthcare workers or patients – remains experimental in nature. It remains to be seen, even with existing widely used medical service robots, whether the benefits promised by these systems is realized. These systems may vary in performance depending on environmental conditions such as network capabilities, audio noise, lighting conditions, battery life, and so on. This leads to the final remaining barrier to deployment: cost. The expense of manufacturing and equipping these robot systems often requires a large initial capital investment, as well as a barrage of consumables and maintenance requirements. It further requires additional training for staff, re-vamped workflows, and commonly institutional willpower to continue to support the systems. These fixed and variable expenses need to be sufficiently mitigated by the potential or realized gains of robotic system use.

6. Conclusion

In summary, service robots in healthcare are seen as potentially playing many roles within the patient care setting. In many ways, the health care industry could benefit from increased automation which has been notably absent from this ever-important area. Patients, health care workers, institutions, insurance companies and governments will find that service robots bring significant benefits in terms of leverage and cost reductions in the future while maintaining or improving access, equity, and high-quality health care.

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Conflict of interest

The authors declare no conflict of interest.

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References

[1] D'Ettorre C, Mariani A, Stilli A, Baena FR y, Valdastri P, Deguet A, et al. Accelerating surgical robotics research: A review of 10 years with the da Vinci research kit. IEEE Robotics and Automation Magazine. 2021;**28**(4): 56-78

[2] Lin CA, Shah K, Mauntel LCC, Shah SA. Drone delivery of medications: Review of the landscape and legal considerations. American Journal of Health-System Pharmacy. 2018;**75**(3):153-158

[3] Archibald MM, Barnard A. Futurism in nursing: Technology, robotics and the fundamentals of care. Journal of Clinical Nursing. 2018;**27**(11-12):2473-2480

[4] Gerhardus D. Robot-assisted surgery: The future is here. Journal of Healthcare Management/American College of Healthcare Executives. 2003;**48**(4):242-251

[5] Binder N, Matthäus L, Burgkart R, Schweikard A. A robotic C-arm fluoroscope. International Journal of Medical Robotics and Computer Assisted Surgery. 2005;**1**(3):108-116

[6] Adams JA, Smart W, Mutlu B, Takayama L, Jeong S, Logan DE, et al. A social robot to mitigate stress, anxiety, and pain in hospital Pediatric care. In: Proceedings of the Tenth Annual ACM/IEEE International Conference on Human-Robot Interaction Extended Abstracts. 2015. pp. 103-104

[7] Hung L, Liu C, Woldum E, Au-Yeung A, Berndt A, Wallsworth C, et al. The benefits of and barriers to using a social robot PARO in care settings: A scoping review. BMC Geriatrics. 2019;**19**(1):232

[8] Lifeline Robotics. [cited 2022 Jan 25]. Available from: https://www.lifelinerobotics.com/#careebo-llr-s1

[9] Kovach CR, Taneli Y, Neiman T, Dyer EM, Arzaga AJA, Kelber ST. Evaluation of an ultraviolet room disinfection protocol to decrease nursing home microbial burden, infection and hospitalization rates. BMC Infectious Diseases. 2017;**17**(1):186

[10] UVD - Robots. [cited 2022 Jan 25]. Available from: https://uvd.blue-ocean-robotics.com/robots

[11] Haliburton L, Esfandiari H, Guy P, Anglin C, Hodgson A. A visual odometry base-tracking system for intraoperative C-arm guidance. International Journal of Computer Assisted Radiology and Surgery. 2020;**15**(10):1597-1609

[12] Mukai T, Hirano S, Nakashima H, Kato Y, Sakaida Y, Guo S, et al. Development of a nursing-care assistant robot RIBA that can lift a human in its arms. In: 2010 IEEE/RSJ International Conference on Intelligent Robots and Systems. Vol. 2010. 2010. pp. 5996-6001

[13] Huang H-W, Chai Peter, Ehmke C, Merewether G, Dadabhoy F, Feng A, et al. Agile mobile robotic platform for contactless vital signs monitoring. TechRxiv. Preprint. 2020. pp 1-8

[14] Ava Robotics | Telepresence and Security Robots. [cited 2022 Jan 25]. Available from: https://www.avarobotics.com/

[15] Ewing DR, Pigazzi A, Wang Y, Ballantyne GH. Robots in the operating room—The history. Surgical Innovation. 2004;**11**(2):63-71

[16] Devito DP, Kaplan L, Dietl R, Pfeiffer M, Horne D, Silberstein B, et al. Clinical acceptance and accuracy assessment of spinal implants guided with SpineAssist surgical robot. Spine. 2010;**35**(24):2109-2115

[17] Sukovich W, Brink-Danan S, Hardenbrook M. Miniature robotic guidance for pedicle screw placement in posterior spinal fusion: Early clinical experience with the SpineAssist®. The International Journal of Medical Robotics and Computer Assisted Surgery. 2006;**2**(2):114-122

[18] Sires J, Craik J, Wilson C. Accuracy of bone resection in MAKO Total knee robotic-assisted surgery. The Journal of Knee Surgery. 2019;**34**(07):745-748

[19] Lin J, Yan S, Ye Z, Zhao X. A systematic review of MAKO-assisted unicompartmental knee arthroplasty. The International Journal of Medical Robotics and Computer Assisted Surgery. 2020;**16**(5):1-7

[20] DiMaio S, Hanuschik M, Kreaden U. The da Vinci surgical system. In Surgical Robotics, Systems Applications and Visions. pp. 199-217. Boston, MA: Springer; 2011

[21] Morelli L, Palmeri M, Guadagni S, Franco GD, Moglia A, Ferrari V, et al. Use of a new integrated table motion for the da Vinci xi in colorectal surgery. International Journal of Colorectal Disease. 2016;**31**(9):1671-1673

[22] Panteleimonitis S, Harper M, Hall S, Figueiredo N, Qureshi T, Parvaiz A. Precision in robotic rectal surgery using the da Vinci xi system and integrated table motion, a technical note. Journal of Robotic Surgery. 2018;**12**(3):433-436

[23] Stefanidis D, Wang F, Korndorffer JR, Dunne JB, Scott DJ. Robotic assistance improves intracorporeal suturing performance and safety in the operating room while decreasing operator workload. Surgical Endoscopy. 2010;**24**(2):377-382

[24] Leonard S, Wu KL, Kim Y, Krieger A, Kim PCW. Smart tissue anastomosis robot (STAR): A vision-guided robotics system for laparoscopic suturing. IEEE Transactions on Biomedical Engineering. 2014;**61**(4):1305-1317

[25] Chow D-L, Newman W. Improved knot-tying methods for autonomous robot surgery. IEEE International Conference on Automation Science and Engineering (CASE). 2013;**2013**:461-465

[26] Kang H, Wen JT. Robotic knot tying in minimally invasive surgeries. IEEE/RSJ International Conference on Intelligent Robots and Systems. 2002;**2**:1421-1426

[27] Zhang L, Ye M, Giannarou S, Pratt P, Yang G-Z. Motion-compensated autonomous scanning for tumour localisation using intraoperative ultrasound. Medical Image Computing and Computer-Assisted Intervention – MICCAI 2017. MICCAI 2017. Lecture Notes in Computer Science, vol 10434. Cham: Springer; https://doi.org/10.1007/978-3-319-66185-8_70

[28] Abdelaal AE, Hong N, Avinash A, Budihal D, Sakr M, Hager GD, et al. Orientation matters: 6-DoF autonomous camera movement for minimally invasive surgery. arXiv preprint arXiv:2012.02836. 2020. pp 1-8

[29] Dumont GA, Ansermino JM. Closed-loop control of Anesthesia. Anesthesia Analgesia. 2013;**117**(5):1130-1138

[30] Neckebroek MM, Smet TD, Struys MMRF. Automated drug delivery in Anesthesia. Current Anesthesiology Reports. 2013;**3**(1):18-26

[31] Bie AJRD, Neto AS, van Meenen DM, Bouwman AR, Roos AN, Lameijer JR, et al. Fully automated postoperative ventilation in cardiac surgery patients: A randomised clinical trial. British Journal of Anaesthesia. 2020;**125**(5):739-749

[32] Rubertsson S, Lindgren E, Smekal D, Östlund O, Silfverstolpe J, Lichtveld RA, et al. Mechanical chest compressions and simultaneous defibrillation vs conventional cardiopulmonary resuscitation in out-of-hospital cardiac arrest: The LINC randomized trial. Journal of the American Medical Association. 2014;**311**(1):53-61

[33] Boehler Q, Gage DS, Hofmann P, Gehring A, Chautems C, Spahn DR, et al. REALITI: A robotic endoscope automated via laryngeal imaging for tracheal intubation. IEEE Transactions Medical Robotics Bionics. 2020;**2**(2):157-164

[34] Wang X, Tao Y, Tao X, Chen J, Jin Y, Shan Z, et al. An original design of remote robot-assisted intubation system. Scientific Reports. 2018;**8**(1):13403

[35] Stoianovici D, Cleary K, Patriciu A, Mazilu D, Stanimir A, Craciunoiu N, et al. AcuBot: A robot for radiological interventions. IEEE Transactions on Robotics and Automation. 2003;**19**(5): 927-930

[36] Owens JA. Sleep loss and fatigue in healthcare professionals. The Journal of Perinatal & Neonatal Nursing. 2007;**21**(2):92-100

[37] Zou X, Liu S, Li J, Chen W, Ye J, Yang Y, et al. Factors associated with healthcare workers’ insomnia symptoms and fatigue in the fight against COVID-19, and the role of organizational support. Frontiers in Psychiatry. 2021;**12**:652717

[38] Mansueto G, Lopes FL, Grassi L, Cosci F. Impact of COVID-19 outbreak on Italian healthcare workers versus general population: Results from an online survey. Clinical Psychology & Psychotherapy. 2021;**28**(6): 1334-1345. DOI:10.1002/cpp.2644

[39] Hou T, Yin Q, Cai W, Song X, Deng W, Zhang J, et al. Posttraumatic stress symptoms among health care workers during the COVID-19 epidemic: The roles of negative coping and fatigue. Psychology, Health & Medicine. 2021, **27**(2):367-378

[40] Saadatzi MN, Logsdon MC, Abubakar S, Das S, Jankoski P, Mitchell H, et al. Acceptability of using a robotic nursing assistant in health care environments: Experimental pilot study. Journal of Medical Internet Research. 2020;**22**(11):e17509

[41] Hills JW, Jensen JF. Telepresence technology in medicine: Principles and applications. Proceedings of the IEEE. 1998;**86**(3):569-580

[42] Nichols KA, Okamura AM. Methods to segment hard inclusions in soft tissue during autonomous robotic palpation. IEEE Transactions on Robotics. 2015;**31**(2):344-354

[43] Priester AM, Natarajan S, Culjat MO. Robotic ultrasound Systems in Medicine. IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control. 2013;**60**(3):507-523

[44] Adams SJ, Burbridge BE, Badea A, Langford L, Vergara V, Bryce R, et al. Initial experience using a Telerobotic ultrasound system for adult abdominal sonography. Canadian Association of Radiologists' Journal. 2017;**68**(3): 308-314

[45] DeBusk W. Unmanned aerial vehicleSystems for Disaster Relief:

Tornado alley. AIAA Infotech@ Aerospace. 2010;2010. pp 1-10

[46] Balasingam M. Drones in medicine—The rise of the machines. International Journal of Clinical Practice. 2017;**71**(9):e12989

[47] Ling G, Draghic N. Aerial drones for blood delivery. Transfusion. 2019;**59**(S2):1608-1611

[48] BUDDY the Emotional Robot. [cited 2022 Jan 25]. Available from: https://buddytherobot.com/en/buddy-the-emotional-robot/

[49] Šabanović S, Bennett CC, Chang W-L, Huber L. PARO robot affect diverse interaction modalities in group sensory therapy for older adults with dementia. 2013 IEEE 13th Int Conf Rehabilitation Robotics ICORR. IEEE. 2013;**2013**:1-6

[50] Embodied Moxie – Embodied, Inc.. [cited 2022 Jan 25]. Available from: https://embodied.com/

Chapter 3

Understanding the Assistive Potential of Consumer Technologies: A Case Example of Smartphones, Smart Speakers, and Internet of Things Technologies

Bryan Boyle and Fiachra O'Brolcháin

Abstract

Assistive technology by its very design seeks to maintain, improve, or facilitate the functional capabilities of people with disabilities and older people. Traditionally, assistive technologies have been specialist in nature defined by the functional capabilities that it is linked to. However, digital consumer technologies such Digital Voice Assistants are increasingly building ever greater functionality in efforts to appeal to users, including those with disabilities. Aimed at a general market as opposed to being restricted to people with a disability, consumer products, with their lower cost thresholds, can provide a good ratio of social return on investment. Furthermore, the growing interoperability of technologies such as smartphones, smart speakers, and internet of things is building hitherto unanticipated opportunities for people with disabilities. This chapter examines the assistive potential of a range of consumer digital technologies and explores how they can benefit people with disabilities and older people. Issues pertaining to risks to personal information, autonomy as well as consent while using these technologies are also outlined. Finally, this chapter concludes with reflections as to how future consumer products can seek to balance the benefits that can be accrued from their use with concerns for respecting the privacy of people with disabilities.

Keywords: consumer technology, mainstream, digital technologies, disability, privacy, autonomy

1. Introduction

As the number of people with disabilities actively using technology to support their day-to-day activities increases, the benefits afforded by these technologies are ever more evident [1].[1] As the use of technology by people with disabilities

[1] Assistive Technology for People with Disabilities and Older People (2016) Available from: https://www.enableireland.ie/sites/default/files/publication/AT%20Paper%20final%20version.pdf

increases opportunities for communication, accessing information and engaging with online services are extended. Much of the technology used by people with disabilities is often characterized as assistive technology (AT) which is designed and developed to address the specific needs of people with disabilities. Such AT is often designed for a specific group of people with disabilities and aims to address a specific need or requirement. For example, people with visual disabilities may seek to use specialist text-to-speech software to present text-based information available in auditory form. For many people with disabilities however, they are excluded from using AT by factors such as the awareness of the technology, the prohibitive cost of specialist technology, and the requirement for installation, training, and support [2–4].

In contrast to AT which is focused on serving the needs of people with disabilities, consumer digital technology refers to those technologies that are developed for use by the general public [ref]. Increasingly, digital consumer technologies are building ever greater functionality in efforts to appeal to as wide a range of users as possible.

Such digital consumer devices include computers [5], smartphones [6], tablets [7], smart TVs [8], and smart speakers [9]. Aimed at a general market as opposed to being restricted to people with a disability, consumer products, with their lower price points, can significantly reduce costs and provide a good ratio of social return on investment [10]. The increased awareness of digital consumer technologies by the general population has served to increase awareness of new and previously unimagined opportunities for people with disabilities [11]. Despite the evident potential of technology for people with disabilities some ethical concerns relating to the use of such consumer technologies remain, although some ethical issues apply equally those with and without disabilities some aspects are particular to persons with disabilities and merit consideration.

The forthcoming sections will explore the assistive potential of a range of exemplar consumer digital technology, smartphones, smart speakers, and internet of things. While highlighting the potential benefits that can be accrued by people with disabilities, we will also explore some of the incumbent risks that consumers with disabilities may need to be aware of and consider when making decisions about using such technologies to support them in their day-to-day lives.

2. Background

A non-discriminatory analysis of the Convention on the Rights of People with Disabilities suggests that the right to affordable and accessible technologies to support participation by citizens with a disability should be seen as a national and international requirement for those to sign up to the ambitions of the convention [12]. Despite such commitments to ensure equitable provision for all people with a disability many see their needs regarding technology remaining unmet [13]. Research has highlighted several barriers that still limit the provision of technology for those with a disability who would benefit most from it. These barriers include lack of information, the probative cost, and the support requirements for specialist assistive technologies [2]. As accessing assistive technology has become more challenging for people with disabilities, awareness has increased as to the potential for mainstream consumer technologies to meet those needs previously addressed by specialist assistive technologies [11].

3. Smartphone: supporting communication and digital experiences for people with disabilities

For many people with disabilities, smartphones are central to their day-to-day digital experiences [14]. Smartphones refer to a category of mobile technologies primarily used for telephony that typically have the processing power to perform many functions associated with personal computers including providing users with multimedia functions such as photos, audio, and video. Smartphones afford users internet access, email, and web-browsing alongside features such as location detection and navigation. Many of the devices that proliferate the smartphone market are equipped with touchscreens, which allow users of different abilities to modify the ways in which they interact with and control the functions available. Coupled with the presence of digital voice assistants such as SIRI and Google Assistant the functionality offered by modern smartphones is accessible for a broad range of people with motor, sensory, and cognitive disabilities [15–17].

The capacity to install and use third-party apps on smartphones further extends their assistive potential for people with disabilities. A significant proportion of devices in the smartphone market utilize one of two main operating systems, IOS for Apple products and the Android operating system which is licensed for use by such brands as Sony, Samsung, and Huawei. These two operating platforms come with a range of "native" features and apps including a range of accessibility features such as magnification and text to speech for users with visual impairments, visual alerts, and hearing aid connectivity for those with hearing disabilities and voice, switch, and gesture control for those with mobility challenges.

Both operating systems have designed a relatively straightforward application ecosystem to allow users to purchase and/or install apps for their own phone and in many cases personalize these for their own use. The range of apps available across both platforms has grown exponentially over the past number of years with many specialized assistive technology products such as screen-readers for visually impaired users and text-to-speech apps for those with communication disabilities becoming available as apps. The availability of alternative and augmentative communication (AAC) apps alongside the native functions in smartphones offers those with communication disabilities a relatively low-cost solution to support them in expressing needs and engaging in social discourse with others [18–20, 21, 22]. Those designing AAC apps are also seeking to harness the additional functionality available on smartphones such as location awareness and context history to build communication solutions that are more responsive to the needs of those with language impairments as they seek to communicate across different environments with different people [23]. For users with developmental challenges and cognitive disabilities, the features available on most smartphones alongside a range of specifically chosen apps can support the performance of activities of daily living [19, 24] and improve their self-management skills [25].

4. Case Study 1: "fitting in," using a smartphone as an alternative to specialist technology for a teenager with a visual impairment

Rosalie describes herself as a "blind teenager" who is currently preparing for her state exams and hopes to progress to university to study Economics and Political Science. She uses a range of technology including a laptop and braille notetaker. It is however her iPhone that she insists is of most value to her.

> *"Because of the native text to speech and the apps that I have added, there is pretty much nothing my phone can't do. WhatsApp keeps me in touch with my friends, the map and navigation apps stop me from getting lost and having the internet in my pocket is all that I need when I am in school and with my friends. Oh and of course, I can always use it as a phone if I need to talk to my parents, but not so much."*

She has had technology in various guises since early childhood but reflects on the advantages she accrues from using a smartphone:

> *"I was always a child with so much equipment, I had a braille keyboard another braille reader and a laptop from the time that I was very young. All were incredibly useful, but if I'm honest I don't miss any of them. I feel like all my equipment has shrunk and has been sucked into my phone. I prefer being the girl with a phone instead of the girl with all the tech, that is just way more normal in my world."*

5. Smart Speakers to support safety and independence in the homes of people with disabilities

Smart Speakers, otherwise referred to as digital voice assistants, refer to devices and applications that constitute data-based programs and devices, which can communicate with human users and respond to their requests primarily through voice commands [26]. For many users, the primary function for smart speakers in a home environment includes offering voice control of daily tasks such as setting alarms, reminding of schedule, and playing music. Manufacturers of smart speakers such as Amazon have also sought to offer users new opportunities for online shopping and e-commerce [27]. Beyond scheduling, setting alarms, and shopping, other uses of smart speakers include accessing media, hands-free information retrieval, and controlling third-party technologies such as smart bulbs, sockets, and media devices [28].

A scoping review of published literature has highlighted the potential for smart speakers to be utilized in a diverse range of interventions and provide functional opportunities for people with sensory, motor, cognitive, and emotional disabilities [29]. Smart speakers are increasingly seen in use across a wide range of services for people with disabilities including in healthcare, rehabilitation, and education. An example of one such application saw smart speakers used as an element of a music-guided stress reduction program that allowed personalization of one's intervention [30]. Other studies highlight the use of smart speakers to improve verbal and social interaction skills for autistic children [31]. During the COVID pandemic, therapists looked to use smart speakers as a way of maintaining provision of services such as Speech and Language Therapy [32].

Although smart speakers are clearly not designed with the needs of people with visual disabilities in mind, the fact that they are operated and controlled by voice offers a range of possibilities. A recently published study describes the use of smart speakers to offer people with visual impairments in educational contexts ways in which they can easily study texts, listen to course content, and get answers to basic queries [33]. Marvin describes the development of a smart speaker application that utilizes the voice interaction and audio feedback functions to provide people with a visual impairment help recognizing text displayed on real world [34]. For users with intellectual or cognitive disabilities interacting with technology using voice offers a new way of accessing information and services from the web [35]. Smart speakers can function as a cognitive "assistant" supporting concentration and attention when performing tasks [36]. Similarly, harnessing smart speakers' auditory and conversational feedback may have potential in supporting older people in home environments particularly those experiencing declining cognitive functions [37]. Further applications exploiting the functions of smart speakers for older people include supporting management of type II diabetes [38] and in avoiding the effects of sedentarism through active monitoring and prompting for regular physical activity [39]. Research focused on the assistive features and functionality of such devices appears to be increasing and offers manufacturers a potential roadmap for further expansion of their consumer reach among people with a disability and older people.

6. Case study 2: freedom and security at home using smart speakers

Jim is a 29-year-old who has a diagnosis of cerebral palsy. This affects his mobility such that he uses a power wheelchair to mobilize in his home and out in his community. He lives with his partner Imelda who has spina-bifida. Similarly, Imelda uses a power wheelchair to support her mobility. They both live in an apartment that has been built adjacent to Jim's parent's home and they have paid carers who help them with activities of daily living in their homes. With the help of some of their family and friends they have installed an Amazon Echo Show smart speaker with screen and have replaced all household lights with Philips Hue Smart Bulbs and all electrical sockets can be operated *via* their smart speaker. They have recently installed a Ring video doorbell and can now see who is calling at their door *via* the visual display on their Echo Show smart speaker.

> *"My main motivation was security, there is no point in denying it, we're both what you might consider vulnerable and I didn't want to trust carers with keys to my home, being able to see who's at the door and to choose to let them in or not makes me feel more secure": Imelda*

> *"People would probably describe me as a 'geek', but I've always been interested in technology because it has allowed me to do things that my hands and legs won't allow me to."*

> *"For me it's the freedom that it gives us to switch off the lights in our own home at night and the ability to just use our voice to switch on some music or the TV, you can't put a prices on that freedom."*
> *Jim*

7. The Internet of Things: the promise of affordable "smart-homes" for people with disabilities

Developments in recent years in networked, wireless, and internet-based technologies including what is referred to as Internet of Things (IoT) have opened a realm of possibilities for people with disabilities. IoT has seen a range of technologies previously referred to as "smart-home technologies" come to the mainstream market at a price threshold well below that of specialist, disability-specific technology [40]. Advances in cloud computing have ensured stable connectivity and data exchange between ever more household objects. Within a typical home environment, the IoT often refers to the connectivity between common appliances such as kettles, fridges, lights, doors, cookers [41]. It can often refer to devices that support the running and maintenance of the building including alarms, heating, energy management, and water [42, 43]. It also serves to provide control and access to home entertainment systems and even toys [44]. For people with disabilities and older people, connecting everyday objects and changing how we as human operators interact and engage with these offer a broad scope for future development of applications in domains such as accessing information and services, manufacturing, logistics and transportation, eHealth, and smart homes and cities.

A recent European Commission report summarized some potential areas where emergent, networked technologies (IoT) might support people with a disability. These include the following:

1. Seeking assistance and help from outside the home environment.

2. Monitoring health conditions and identifying emergent health issues.

3. Supporting the delivery of medication and other health interventions.

4. Environmental automation—automatically adjusting the immediate ambient conditions, e.g., light, heat, ventilation.

5. Intelligent transportation [45].

Much of the reported research pertaining to the use IoT technologies for people with disabilities and older people examines and explores its application in smart-home solutions. Many of those smart-home solutions see IoT technologies paired with voice-controlled technologies such as smart speakers or smartphones thus extending the application of this range of consumer devices. The benefits of IoT for those with mobility difficulties include savings in exertion and decreased risk that devices such as smart-plugs and remotely controlled lights [46]. For those whose disability impacts their mobility IoT technologies can play a role in providing greater independence outside of their homes and throughout their communities [47].

Published literature also describes how the application of IoT technologies can support people with visual disabilities [48], people with cognitive or intellectual disabilities [49], people who are deaf or hard of hearing [50], and those with mental health issues [51]. For older people and those who spend more times in their homes due to their disabilities applications for IoT technologies include calling for help in emergencies, staying in contact with relatives and friends, monitoring their health status [52], and controlling lights and home temperature [53]. IoT offers vulnerable users and their families with opportunities to increase safety in home environments using technologies to detect falls and alert others [54, 55].

Much has been made of the possibilities available when most household objects can be incorporated into the IoT, including smart fridges that can support activities such as shopping, health eating, and budgeting [56, 57]. Similarly, developments in other objects such as the shower [58], cooker [59], and washing machines [60]. Despite reports of the potential of such connected IoT devices, to date there has been limited transfer of this potential to market ready consumer technologies. The reported benefits of IoT technologies currently available to consumers are limited to a narrow range of functions including controlling lighting and electrical sockets. This can be seen as reflective of the limited number of "smart-devices" currently available to the mainstream market.

The potential of IoT technologies remains somewhat speculative, as such how they may potentially serve the needs of people with disabilities remains unexplored. It is likely that the full potential of these emergent technologies will unfold as more and more products come to market and is more readily available to all consumers. It must be remembered, however, that as with smartphone and smart speakers it is likely that the applications of IoT technology for people with disabilities will be led by the emerging functionality of the technology rather than the expressed needs of users [49, 61].

8. Ethics and privacy considerations for people with disabilities

In examining some of the ethical issues that pertain to the use of many of the consumer digital technologies described here, it is worth considering their use within a broader political and economic context. As mentioned previously, people with disabilities are not the constituency for which many of these technologies are designed for. Rather they have been developed for widescale use by broad swathes of the general consumer market and are motivated by the commercial imperatives of large-scale corporations such as Amazon, Google/Alphabet, or Apple. One commercial rationale for such technologies is to leverage their ability assist large companies and corporations to compete, to varying degrees, for people's data to better attract, retain, and direct users' attention. The ease at which consumer technologies are used to gather user data, the extent of the data harvested, and the uses to which it is put is not easy to determine. This may partially be understood when we consider that large tech corporations are coy about exactly how their technologies are designed to detect our voices and why. In the case of Amazon, the developer of the Echo smart speaker range, much of their technologies are based on patents that list a range of traits they might collect, including identity and feelings [62].

A primary concern for those interested in examining the ethics of using consumer technologies use by people with disabilities is how an individual's privacy may be impacted. Privacy is a complicated and contested construct, one which must be considered from a broad range of perspectives. It is often considered that privacy is not only subjective but is interpreted differently in legislative and cultural contexts [63, 64]. Despite these challenges with definition, there exists a consensus that privacy is of great importance across all societies. This is reflected in several international documents that enshrine privacy as a basic human right [65, 66]. According to these documents, states, institutions, and individuals have a general obligation to respect privacy. For smartphones and smart speakers in particular, their functioning depends on their ability to listen to users and to store and manipulate this data. In the case of smart speakers, these technologies are designed to have the capacity to continuously listen to users and to events in their homes thus creating risks to and potentially a significant threat to people with disabilities' privacy. Different datasets have the potential to reveal much about the user, including information that could be revealing of habits, preferences (political, cultural, sexual), psychological well-being, and physical health. When considered in combination with each other, smartphones, smart speakers, and internet of things technologies can be seen to represent an aural network capable of impacting a person's confidentiality, anonymity, and accountability in the process becoming a new burden on the user. For people with disabilities their rights to decisional privacy highlight the importance of being able to decide without (undue) influence from third parties such as healthcare providers, insurance companies, or commercial entities, for example, online shopping or financial services. A further dimension worth considering for people with disabilities is the right to physical privacy which is concerned with issues such as bodily modesty and intimate events. Access to data and the ability to draw inferences from such data could potentially reveal a person's care needs and their vulnerabilities, information that could present as attractive to malevolent agents. Similarly, associational privacy relates to an individual's ability to choose with whom one associates. Smartphones, by the nature of their functionality and the data they store locally and across networks, risk disguising new associations with those that store or whoever might buy that data.

Large corporate entities such as Amazon, Google, and Apple are not oblivious to the potential ways in which using their products can impose upon an individual's privacy, including that of people with disabilities. In efforts to address these risks, and potentially to minimize the liability of such risks using their technologies, services are conditional on the user agreeing to the terms and conditions of using a DVA, i.e., they have given their consent. This, however, presupposes that the user has read or understood the terms of the contract. For some people with disabilities where their cognition or capacity for understanding is compromised, the explicit provision of consent that is informed and offered willingly can be problematic. Furthermore, it is also possible to question the fairness of such a contract between technology provider and user in the first instance. The provision of consent implies that users are fully informed about what is being recorded and a requirement to determine how the data gathered may potentially be used. While the value of ensuring transparent processes to support the informed consent for people with disabilities has been recognized in medical ethics for the past few decades, it has only recently entered debates around big data, data mining, and novel technologies [67–69]. Informed consent "is usually understood as informed, voluntary and competent consent" [70]. In the event that a person is using a technology that is capable of recording, storing, and re-purposing information about a person's disability or functioning the issue of informed consent is even more pertinent. Disabilities and those that experience them are varied, forming a wide spectrum of capacity and ability. Within any cohort of people with a disability, some will have the ability to provide informed consent. For others, fully informed consent may only be possible under the right conditions and where everything has explained clearly. For some however, it may be that the ability to consent to one's what may happen to one's data when using such consumer technologies may not be possible. As the risks associated with using consumer products that have the capability of harvesting personal data increase, it is conceivable that the market may contract as individuals become more concerned with the risks to the autonomy of their own data and to their privacy. For segments of the consumer market with additional vulnerabilities in terms of the risks, they may face manufacturers and service providers such as large corporations may need to move beyond a one-size-fits-all model of how data is collected and managed. The procedures around informed consent for commercially available digital technologies such as smartphones, smart speakers, and internet of things may need to be adapted to accommodate these requirements.

9. Case study 3: benefits and risks: trading privacy for independence

Damian works as a freelance journalist and lives at home with his wife and two young children. He was diagnosed 7 years with Multiple Sclerosis which has had an impact on his mobility and how he manages his fatigue. He uses a smartphone primarily as a means of doing his job as a journalist and uses Google Hub with a Hive thermostat to control his home heating and with smart plug sockets so he can minimize physical exertion in activities in his home.

> *"Maybe because of the work that I do, I am more aware of the risks, there is a sense, particularly with the Google Hub that someone is listening all the time. But I remind myself that the benefit to me, to these devices help me manage my energy during the day, it outweighs the risk that someone is listening in to my conversations with contacts or studying what I am doing here in my own home. I don't spend a great deal of time worrying about it, but I do have to be aware that I have an incurable neurological condition and that is not something that I want everyone to necessarily know about, I do have concerns that information might get out there. That is something that I do need to consider."*

10. Summary and conclusions

The uptake of consumer digital technologies by people with disabilities suggests that accessibility and equality goals can best be met through leveraging the potential of these technologies [71]. It must, however, be recognized that the assistive potential of many of these technologies were never designed to ensure equity of access for people with disabilities, rather they were designed to appeal to as broad a swathe of the consumer market as possible. Features such as voice-control, touchscreen access, text to speech, and other features provided opportunities for those with diverse motor, sensory, and cognitive needs to use the technology. Furthermore, the ability to access the technology ensured that users with diverse needs could in turn exploit the broad functionality of these "connected" devices. It may be too soon to herald the decline of very specialized assistive technologies in favor of what must be considered "accessible" consumer technologies. It is clear, however, that the availability and costs associated with consumer digital technologies should result in more people with disabilities using these, perhaps alongside more specialist, bespoke solutions. It is reasonable to assume that as awareness increases of people with disabilities as a sizeable market segment further attention will be given to developing expanded functionality aimed at addressing some of their specific needs.

Consumer digital technologies undoubtedly present opportunities for many users with diverse needs and requirements. This includes making it easier to access the online world, control other devices, communicate readily with others, and live their best digital lives. There is, however, a growing debate about the potentially intrusive nature of such "connected" devices and the use of the data captured. The potential technology can offer people with a disability must be balanced against the need to ensure their right to information privacy and security [10]. Concerns regarding safety, privacy, and autonomy have the potential to erode the confidence people with a disability have in the choice making and control available to them. Companies such as Amazon, Apple, and Microsoft, among others, may see the market for their products diminish if the concerns of people with disabilities begin to outweigh the perceived benefits of using these technologies. Leading analysts such as Forbes have estimated that anywhere between $10 and $16 billion will be spent on realizing accessibility requirement for consumer digital products[2]. Recent online debates, however, point to a growing awareness of the

[2] https://www.forbes.com/sites/forrester/2021/07/01/how-10b-in-design-spending-will-soon-be-up-for-grabs-annually/?sh=2bda56611ea9 (accessed January 2023).

problems associated with disassociating ethical considerations from the design of new technologies[3]. A recognition that people with disabilities and older people are a market segment for consumer technologies that is likely to grow exponentially over the next few years has focused the attention of these companies. Legislative changes in Europe including the eAccessibility Act [72] promise more market opportunities for accessible technologies and accompanying services. Furthermore, such legislation builds upon previous efforts to ensure that safeguards are in place to assure all citizens as to their rights to digital privacy [73]. Efforts are also underway by advocacy bodies such as the European Disability Platform have sought to increase awareness of the issue through the publication of policy and guidance statements.[4]

While legislation alone may not fully address some of the concerns of people with disabilities, it is, however, likely to increase their opportunities to purchase these technologies with the same consumer rights as all other users. It is likely that an increased uptake in these consumer devices by people with disabilities will open greater opportunities for discussion and debate as to how greater access to the benefits of the technology can be balanced with the need to ensure the privacy and autonomy of consumers with disabilities.

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Conflict of interest

The authors declare no conflict of interest.

[3] https://medium.com/tribalscale/design-ethics-and-technology-d294ce15f29d (accessed January 2023).

[4] https://www.edf-feph.org/data-protection-policy/ (accessed January 2023).

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References

[1] Ireland E. Assistive Technology for People with Disabilites and Older People: A Discussion Paper. Dublin: Disability Federation of Ireland; 2016

[2] Boot FH, Owuor J, Dinsmore J, Maclachlan M. Access to assistive technology for people with intellectual disabilities: a systematic review to identify barriers and facilitators. Journal of Intellectual Disability Research 2018;**62**(10):900-921. Available from: https://pubmed.ncbi.nlm.nih.gov/29992653/

[3] Draffan EA, James A, Cudd P, Bentley C. Barriers and facilitators to uptake of assistive technologies: Summary of a literature exploration. Studies in Health Technology and Informatics. 2015;**21**(217):350-356

[4] Copley J, Ziviani J. Barriers to the use of assistive technology for children with multiple disabilities. Occupational Therapy International. 2004;(4):229-243

[5] Kasulaitis BV, Babbitt CW, Kahhat R, Williams E, Ryen EG. Evolving materials, attributes, and functionality in consumer electronics: Case study of laptop computers. Resources, Conservation and Recycling. 2015;**100**:1-10

[6] Boulos MNK, Wheeler S, Tavares C, Jones R. How smartphones are changing the face of mobile and participatory healthcare: an overview, with example from eCAALYX. Biomedical Engineering Online. 2011;**5**(10):24

[7] Yoshizawa H, Ishida M, Yoshitsuru T. Development of and future prospects for tablet devices. Fujitsu Scientific & Technical Journal. 2013;**1**(49):208-212

[8] Khan M, Khusro S, Alam I, Ali S, Khan I. In: Ali R, editor. Perspectives on the Design, Challenges, and Evaluation of Smart TV User Interfaces. Vol. 2022. Sci Program; 2022. p. 2775959

[9] Tavares R, Sousa H, Ribeiro J. Smart speakers and functional diversity: A scoping review. In: Costa AP, Moreira A, Sánchez-Gomez MC, Wa-Mbaleka S, editors. Computer Supported Qualitative Research WCQR 2022 Lecture Notes in Networks and Systems. Vol. 466. 2022. pp. 48-64. Available from: https://link.springer.com/10.1007/978-3-031-04680-3_4

[10] Lazar J, Goldstein D, Taylor A. The discriminatory impact of digital inaccessibility. In: Ensuring Digital Accessibility Through Process and Policy. Elsevier; 2015 p. 41-58. Available from: https://linkinghub.elsevier.com/retrieve/pii/B9780128006467000034

[11] Botelho FHF. Childhood and Assistive Technology: Growing with opportunity, developing with technology. Assistive Technology. 2021;**33**(sup1)

[12] Borg J, Larsson S, Östergren PO. The right to assistive technology: for whom, for what, and by whom? Disabil Soc. 2011;**26**(2):151-167

[13] Work Research Centre. Assistive Technology Usage and Unmet Need amongst People with Disabilities in Ireland. Dublin; 2015

[14] Morris J, Sweatman M, Jones M. Smartphone use and activities by people with disabilities: 2015-2016 Survey. Journal on Technology and Persons with Disabilities. 2017:5

[15] Grussenmeyer W, Folmer E. Accessible touchscreen technology for people with visual impairments. ACM

Trans Access Comput. 2017;**9**(2):1-31. Available from: https://dl.acm.org/doi/10.1145/3022701

[16] Skogly Kversøy K, Kellems RO, Kuyini Alhassan AR, Bussey HC, Daae Kversøy S. The emerging promise of touchscreen devices for individuals with intellectual disabilities. Multimodal Technologies and Interaction. 2020;**4**(4):70. Available from: https://www.mdpi.com/2414-4088/4/4/70

[17] Stephenson J, Limbrick L. A review of the use of touch-screen mobile devices by people with developmental disabilities. Journal of Autism and Developmental Disorders 2015;**45**(12):3777-3791. Available from: http://link.springer.com/10.1007/s10803-013-1878-8

[18] Ghatkamble R, Son J, Park D. A Design and Implementation of Smartphone-Based AAC System. Journal of the Korea Institute of Information and Communication Engineering. 2014;**18**(8):1895-1903. Available from: http://koreascience.or.kr/journal/view.jsp?kj=HOJBC0&py=2014&vnc=v18n8&sp=1895

[19] Lancioni GE, Singh NN, O'Reilly MF, Sigafoos J, Alberti G, Zimbaro C, et al. Using smartphones to help people with intellectual and sensory disabilities perform daily activities. Frontiers in Public Health. 2017;**5**:282. Available from: http://journal.frontiersin.org/article/10.3389/fpubh.2017.00282/full

[20] King G. Perspectives on measuring participation: going forward. Child: Care, Health and Development. 2013;**39**(4):466-469. Available from: http://doi.wiley.com/10.1111/cch.12083

[21] Lancioni GE, Singh NN, O'Reilly MF, Sigafoos J, Alberti G, Perilli V, et al. An upgraded smartphone-based program for leisure and communication of people with intellectual and other disabilities. Frontiers in Public Health. 201;**6**:234. Available from: https://www.frontiersin.org/article/10.3389/fpubh.2018.00234/full

[22] King M, Romski M, Sevcik RA. Growing up with AAC in the digital age: a longitudinal profile of communication across contexts from toddler to teen. Augmentative and Alternative Communication 2020;**36**(2):128-141. Available from: https://www.tandfonline.com/doi/full/10.1080/07434618.2020.1782988

[23] Sazzad Hossain M, Takanokura M, Sakai H, Katagiri H. Using context history and location in context-aware AAC systems for speech-language impairments. Lecture Notes in Engineering and Computer Science: In; 2018

[24] Lancioni GE, Singh NN, O'Reilly MF, Sigafoos J, Alberti G, del Gaudio V, et al. People with intellectual and sensory disabilities can independently start and perform functional daily activities with the support of simple technology. PLoS One. 2022;**17**(6):e0269793. DOI: 10.1371/journal.pone.0269793

[25] Dicianno BE, Fairman AD, McCue M, Parmanto B, Yih E, McCoy A, et al. Feasibility of using mobile health to promote self-management in Spina Bifida. American Journal of Physical Medicine & Rehabilitation 2016;**95**(6):425-437. Available from: https://journals.lww.com/00002060-201606000-00004

[26] Hoy MB. Alexa, Siri, Cortana, and More: An introduction to voice assistants. Medical Reference Services Quarterly. 2018;**37**(1):81-88

[27] Moriuchi E. Okay, Google!: An empirical study on voice assistants on consumer engagement and loyalty. Psychology and Marketing. 2019;**36**(5):489-501

[28] Ammari T, Kaye J, Tsai JY, Bentley F. Music, Search, and IoT. In: ACM Transactions on Computer-Human Interaction (TOCHI). ACM PUB27. New York, NY, USA; 2019

[29] Tavares R, Sousa H, Ribeiro J. Smart speakers and functional diversity: A scoping review. In: Costa AP, Moreira A, Sanchez-Gomez MC, Wa-Mbaleka S, editors. Computer Supported Qualitative Research. Cham: Springer International Publishing; 2022. pp. 48-64

[30] Siegert I, Busch M, Metzner S, Junne F, Krüger J. Music-Guided Imagination and Digital Voice Assistant – Study Design and First Results on the Application of Voice Assistants for Music-Guided Stress Reduction. 2022 [cited 2022 Jun 26];347-62. Available from: https://link.springer.com/chapter/10.1007/978-3-031-05014-5_29

[31] Safi MF, al Sadrani B, Mustafa A Virtual voice assistant applications improved expressive verbal abilities and social interactions in children with autism spectrum disorder: A Single-Subject experimental study. Int J Dev Disabil. 2021;1-13. Available from: https://www.tandfonline.com/doi/full/10.1080/20473869.2021.1977596

[32] Kulkarni P, Duffy O, Synnott J, George Kernohan W, McNaney R. Speech and language practitioners' experiences of commercially available voice-assisted technology: Web-based survey study. JMIR Rehabil Assist Technol.5 Jan 2022;**9**(1):e29249. Available from: https://rehab.jmir.org/2022/1/e29249.

[33] McNally B, Mauriello ML, Guha ML, Druin A. Gains from participatory design team membership as perceived by child alumni and their parents. In: Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems - CHI '17. New York, New York, USA: ACM Press; 2017. pp. 5730-5741. Available from: http://dl.acm.org/citation.cfm?doid=3025453.3025622

[34] Marvin E. Digital Assistant for the Visually Impaired. In: 2020 International Conference on Artificial Intelligence in Information and Communication (ICAIIC), Fukoka Japan: IEEE; 2020. p. 723-728. Available from: https://ieeexplore.ieee.org/document/9065191/

[35] Balasuriya SS, Sitbon L, Bayor AA, Hoogstrate M, Brereton M. Use of voice activated interfaces by people with intellectual disability. In: Proceedings of the 30th Australian Conference on Computer-Human Interaction. New York, NY, USA: ACM; 2018. pp. 102-112. Available from: https://dl.acm.org/doi/10.1145/3292147.3292161

[36] Mechling LC, Gast DL, Seid NH. Evaluation of a personal digital assistant as a self-prompting device for increasing multi-step task completion by students with moderate intellectual disabilities. Educ Train Autism Dev Disabil. 2010;**45**(3):422-439

[37] Baldauf M, Bösch R, Frei C, Hautle F, Jenny M. Exploring requirements and opportunities of conversational user interfaces for the cognitively impaired. In: Proceedings of the 20th International Conference on Human-Computer Interaction with Mobile Devices and Services Adjunct. New York, NY, USA: ACM; 2018. pp. 119-126. Available from: https://dl.acm.org/doi/10.1145/3236112.3236128

[38] Balsa J, Félix I, Cláudio AP, Carmo MB, Silva IC Guerreiro A et al. Usability of an Intelligent Virtual Assistant for Promoting Behavior Change and Self-Care in Older People with Type 2 Diabetes. Journal of Medical Systems. 2020;**44**(7):130. Available from: https://link.springer.com/10.1007/s10916-020-01583-w

[39] Valera Román A, Pato Martínez D, Lozano Murciego Á, Jiménez-Bravo DM, de Paz JF. Voice assistant application for avoiding sedentarism in elderly people based on IoT Technologies. Electronics (Basel). 2021;**10**(8):980. Available from: https://www.mdpi.com/2079-9292/10/8/980

[40] Lee H, Park YR, Kim HR, Kang NY, Oh G, Jang IY, et al. Discrepancies in demand of internet of things services among older people and people with disabilities, their caregivers, and health care providers: Face-to-face survey study. Journal of Medical Internet Research. 2020;**22**(4):e16614. Available from: http://www.jmir.org/2020/4/e16614/

[41] Moy Chatterjee J, Kumar R, Khari M, Thi Hung D, Le DN. Internet of things based system for smart kitchen. International Journal of Engineering and Manufacturing. 2018;**8**(4):29-39. Available from: http://www.mecs-press.org/ijem/ijem-v8-n4/v8n4-4.html

[42] Kumar S, Tiwari P, Zymbler M. Internet of Things is a revolutionary approach for future technology enhancement: A review. J Big Data. 2019;**6**(1):111. Available from: https://journalofbigdata.springeropen.com/articles/10.1186/s40537-019-0268-2

[43] Khajenasiri I, Estebsari A, Verhelst M, Gielen G. A review on internet of things solutions for intelligent energy control in buildings for smart city applications. Energy Procedia. **2017**:770-779. Available from: https://linkinghub.elsevier.com/retrieve/pii/S1876610217302692

[44] McReynolds E, Hubbard S, Lau T, Saraf A, Cakmak M, Roesner F. Toys that listen: A study of parents, children, and internet-connected toys. Conference on Human Factors in Computing Systems - Proceedings. 2017;2017-May:5197-5207

[45] Vasco Lopes N. Internet of Things feasibility for disabled people. Transactions on Emerging Telecommunications Technologies. 2020;**31**(12). Available from: https://onlinelibrary.wiley.com/doi/10.1002/ett.3906

[46] Mtshali P, Khubisa F. A smart home appliance control system for physically disabled people. In: 2019 Conference on Information Communications Technology and Society (ICTAS). IEEE; 2019. p. 1-5. Available from: https://ieeexplore.ieee.org/document/8703637/

[47] Rashid Z, Melià-Seguí J, Pous R, Peig E. Using Augmented Reality and Internet of Things to improve accessibility of people with motor disabilities in the context of Smart Cities. Future Generation Computer Systems. 2017;**76**:248-261. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0167739X16306860

[48] Leporini B, Buzzi M. Home automation for an independent living. In: Proceedings of the 15th International Web for All Conference. New York, NY, USA: ACM; 2018. pp. 1-9. Available from: https://dl.acm.org/doi/10.1145/3192714.3192823

[49] Ulloa M, Prado-Cabrera D, Cedillo P. Systematic literature review of internet of things solutions oriented to people with physical and intellectual disabilities. In: Proceedings of the 7th International Conference on Information and Communication Technologies for Ageing Well and e-Health. SCITEPRESS - Science and Technology Publications. 2021. pp. 228-235. Available from: https://www.scitepress.org/DigitalLibrary/Link.aspx?doi=10.5220/0010480902280235

[50] Kumari P, Goel P, Reddy SRN. PiCam: IoT based wireless alert system for deaf and hard of hearing. In: 2015 International Conference on Advanced

Computing and Communications (ADCOM). IEEE; 2015. p. 39-44. Available from: http://ieeexplore.ieee.org/document/7529820/

[51] de la Torre Díez I, Alonso SG, Hamrioui S, Cruz EM, Nozaleda LM, Franco MA. IoT-based services and applications for mental health in the literature. Journal of Medical Systems 2019;**43**(1):11. Available from: http://link.springer.com/10.1007/s10916-018-1130-3

[52] Kadhim KT, Alsahlany AM, Wadi SM, Kadhum HT. An overview of patient's health status monitoring system based on Internet of Things (IoT). Wireless Personal Communications 2020;**114**(3):2235-2262. Available from: https://link.springer.com/10.1007/s11277-020-07474-0

[53] Ghorayeb A, Comber R, Gooberman-Hill R. Older adults' perspectives of smart home technology: Are we developing the technology that older people want? International Journal of Human Computer Studies. 2021;**147**:102571. Available from: https://linkinghub.elsevier.com/retrieve/pii/S1071581920301737

[54] Greene S, Thapliyal H, Carpenter D. IoT-Based fall detection for smart home environments. In: Proceedings - 2016 IEEE International Symposium on Nanoelectronic and Information Systems. iNIS; 2017. p. 2016

[55] Vaiyapuri T, Lydia EL, Sikkandar MY, Diaz VG, Pustokhina IV Pustokhin DA Internet of Things and deep learning enabled elderly fall detection model for smart homecare. IEEE Access. 2021;**9**:113879-113888. Available from: https://ieeexplore.ieee.org/document/9471869/

[56] Layton, Steel. The convergence and mainstreaming of integrated home technologies for people with disability. Societies. 2019;**9**(4):69. Available from: https://www.mdpi.com/2075-4698/9/4/69

[57] Trieu Minh V, Khanna R. Application of artificial intelligence in smart kitchen. International Journal of Innovative Technology and Interdisciplinary Sciences www IJITIS.org. 2018;**1**(1)

[58] Ferati M, Babar A, Carine K, Hamidi A, Mörtberg C. Participatory design approach to Internet of Things: Co-designing a smart shower for and with people with disabilities. In: Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics). 2018. pp. 246-261 Available from: https://link.springer.com/10.1007/978-3-319-92052-8_19

[59] Salama D, Minaam A. Smart kitchen: Automated cooker technique using IoT. IJ of Electronics and Information Engineering. 2018;**9**(1)

[60] Wu D. Research on the micro-interactive interface design of intelligent washing machines in IOT environment. In: 2016 22nd International Conference on Automation and Computing (ICAC). IEEE; 2016. p. 479-487. Available from: http://ieeexplore.ieee.org/document/7604966/

[61] Domingo MC. An overview of the Internet of Things for people with disabilities. Journal of Network and Computer Applications 2012;**35**(2):584-596. Available from: https://linkinghub.elsevier.com/retrieve/pii/S1084804511002025

[62] Cox T. The ethics of smart devices that analyze how we speak. Harvard Business Review 2019 [cited 2022 Jun 29]. Available from: https://hbr.org/2019/05/the-ethics-of-smart-devices-that-analyze-how-we-speak

[63] Nissenbaum H. Privacy in Context: Technology, Policy, and the Integrity of Social Life. Stanford, CA, United States: Stanford University Press; 2009

[64] Beauchamp TL, Childress JF. Principles of biomedical ethics. 6th ed. New York: Oxford University Press; 2009

[65] United Nations. Convention on the rights of persons with disabilities. Vol. 2515, Treaty Series. 2006. Available from: http://www.un.org/disabilities/

[66] Council of Europe. Convention for the protection of human rights and dignity of the human being with regard to the application of biology and medicine: Convention on human rights and biomedicine. 1997. Available from: https://www.coe.int/en/web/conventions/full-list?module=treaty-detail&treatynum=164

[67] Eyal N. Informed Consent (Stanford Encyclopedia of Philosophy/Fall 2012 Edition). In: The Standord Encyclopedia of Philosophy Fall. 2012 [Internet]. 2012 [cited 2022 Jun 29]. Available from: https://plato.stanford.edu/archives/fall2012/entries/informed-consent/

[68] Novitzky P, Smeaton AF, Chen C, Irving K, Jacquemard T, O'Brolcháin F, et al. A review of contemporary work on the ethics of ambient assisted living technologies for people with Dementia. Science and Engineering Ethics. 2015;**21**(3):707-765. Available from: http://link.springer.com/10.1007/s11948-014-9552-x

[69] Spiegel JS. The ethics of virtual reality technology: Social hazards and public policy recommendations. Science and Engineering Ethics. 2018;**24**(5):1537-1550. Available from: http://link.springer.com/10.1007/s11948-017-9979-y

[70] Ahlin J. The impossibility of reliably determining the authenticity of desires: Implications for informed consent. Medicine, Health Care, and Philosophy. 2018;**21**(1):43-50. Available from: http://link.springer.com/10.1007/s11019-017-9783-0

[71] Agree EM. The potential for technology to enhance independence for those aging with a disability. Disability and Health Journal. 2014;**7**(1):S33-S39. Available from: https://linkinghub.elsevier.com/retrieve/pii/S1936657413001581

[72] Parliament E. Council of the European Communities. Directive (EU) 2019/882 of the European Parliament and of the Council of 17 April 2019 on the accessibility requirements for products and services. Official Journal of the European Union. 2019

[73] Hoofnagle CJ, van der Sloot B, Borgesius FZ. The European Union general data protection regulation: What it is and what it means. Information & Communications Technology Law. 2019;**28**(1):65-98. Available from: https://www.tandfonline.com/doi/full/10.1080/13600834.2019.1573501

Chapter 4

Perspective Chapter: Vocational Rehabilitation, Information, Communication Technology, and Assistive Technology Devices for Employment

Kai Seino

Abstract

This paper aims to clarify the present and future of ICT and AT devices in the field of vocational rehabilitation in Japan through a literature review. The spread of COVID-19 pandemic in 2020 has led to a rise in the number of telework and remote employment support for persons with disabilities. Such practices are very likely to use ICT, such as email and web conferencing services, as well as associated AT devices. Accordingly, clarifying the current status and future of ICT and AT devices for vocational rehabilitation will be useful in improving the quality of employment support for people with disabilities. First, the devices introduced by disability type on the web page of a public rehabilitation organization in Japan, are summarized, in order to present an overall picture of the status of ICT and AT devices for employment. Secondly, a systematic review was conducted based on the PRISMA flow diagram to identify trends in research on ICT and AT devices for employment of persons with disabilities. The database search and hand search resulted in the selection of 36 papers. The selected studies were classified into "type of disability" targeted and "employment support setting" based on the study objective and content.

Keywords: persons with disabilities, vocational rehabilitation, information and communication technology, assistive technology, assistive technology devices

1. Introduction

1.1 Current situation of ICT and AT devices

According to the Ministry of Internal Affairs and Communications [1], in recent years, information and communication technology (ICT) has become a common entity in Japan, with over 90% of households owning a mobile device such as a cellphone or smartphone. As Apple [2] and Vector inc. [3] point out, these mobile devices include a variety of assistive functions and applications that can be utilized by people with disabilities, such as text-to-speech and speech-to-text, and the line between ICT and assistive technology (AT) devices is beginning to blur.

Additionally, the spread of the novel coronavirus (COVID-19) pandemic in 2020 has led to a rise in the number of companies practicing telework and employment support institutions for persons with disabilities offering remote support [4, 5]. Such telework and remote support practices are very likely to use ICT, such as email and web conferencing services, as well as associated AT devices. Accordingly, clarifying the current status and future of ICT and AT devices for vocational rehabilitation that are used in employment support and working life (hereinafter, ICT and AT devices for employment) will be useful in improving the quality of work and employment support for people with disabilities in the future.

1.2 Changing needs and expectations for ICT and AT devices

In Japan, changes in the needs of people with disabilities due to COVID-19 were discussed at the Labor Policy Council Group Discussion for Employment of Persons with disabilities in October 2020. With respect to a basic understanding of the current situation, they indicated a "growing need for online employment support and telework in response to technological innovations and the novel coronavirus." Furthermore, they presented "consideration of future strategies, including training of those who already have a job and online training in accordance with diverse needs, in coordination with human resource development policy" as a course of action for the time being [6]. Further, in November 2020, it was noted that "the spread of a work-style applying digital technologies such as telework and robotics also has the potential to increase opportunities that enable active participation by people with disabilities for whom employment has previously been difficult" [7]. In other words, there are great expectations for the effective application of new technologies regarding work and employment support for people with disabilities.

1.3 The objective of this paper

In light of these circumstances, this paper aims to clarify the present and future of ICT and AT devices in the field of vocational rehabilitation in Japan through a literature review.

The terms used in this paper are defined as follows: ICT is a generic term for the information and communication environment, including devices used for information and communication. Assistive technology (AT) devices are devices used to reduce the challenges and barriers resulting from the disability and are not limited to devices designed specifically for people with disabilities.

2. Approaches to ICT and AT devices for employment

2.1 ICT and AT devices and assistive technology

The ICT and AT devices discussed in this paper can broadly be defined as assistive technologies (AT). AT was first defined in this way in the United States Technology-Related Assistance for Individuals with Disabilities Act of 1988 [8].

In this law, AT is divided into assistive technology devices and assistive technology services, which are defined as follows: "the term 'assistive technology device' means any item, piece of equipment, or product system, whether acquired commercially off the shelf, modified or customized, that is used to increase, maintain, or improve functional capabilities of individuals with disabilities." "The term 'assistive technology service' means any service that directly assists an individual with a disability in selecting, acquiring, or using an assistive technology device." Such a term includes evaluation and examination; purchasing, leasing, or otherwise providing for acquisition; selecting, designing, customizing, or repairing; and training or technical assistance [9].

2.2 The International organization for standardization (ISO) and the international classification of functioning, disability and health (ICF)

The International Organization for Standardization's (ISO) ISO9999: Assistive Products for Persons with Disability—Classification and Terminology and the World Health Organization's (WHO) (2002) [10] International Classification of Functioning, Disability and Health (ICF) offer exemplary, international definitions related to ICT and AT devices.

First, ISO9999, an international standard for assistive product classification, defines an assistive product as "any product (including devices, equipment, instruments, and software), especially produced or generally available, used by or for persons with disability for participation, to protect, support, train, measure or substitute for body functions/structures or activities, or to prevent impairments, activity limitations, or participation restrictions" [11]. The ISO9999 (2011 edition) establishes the following 12 major classifications: "medical devices," "technical and training devices," "artificial limbs," personal care-related devices," "mobility equipment," "household devices," "furnishings, fixtures, architectural accommodations," "communication and information support devices," "devices for handling objects," "environment-enhancing equipment/work-related devices," "employment/job training devices," and "recreation devices" [12]. The ISO9999 includes a classification for employment-related devices, but in a broader sense, any other devices necessary for employment could also be considered employment-related devices.

Subsequently, in the ICF, an individual's everyday functioning is described as an interaction of health, functioning (1. body and mental functions and body structure, 2. activities, 3. participation), and background factors (1. environmental factors, 2. individual factors). The components of the ICF have a hierarchical structure. "Products and technology" is a sub-classification of environmental factors and includes the further sub-classification of "products and technology for employment." ICT and AT devices for employment would primarily fall into this sub-classification.

3. The status of ICT and AT devices for employment

In this section, the devices currently introduced by disability type on the AT devices for employment page of the National Institute of Vocational Rehabilitation website [13], a public rehabilitation organization in Japan, are summarized as shown

		Type of disability					
		Visual	Hearing	Upper limb	Lower limb	Intellectual	Developmental
Device	**Main function**						
Screen Reading Software	Text-to-speech for PC screen, text, keyboard, etc.	○					
Screen Magnification Software	Magnification of images and text and text-to-speech	○					
Magnification reader	Stationary and portable versions are available	○					
Character Recognition	Speech-to-Speech of Printed Text and Braille	○					
Braille-related equipment	Creates Braille, displays Braille, and reads Braille aloud	○					
Signaling devices	Light, vibration, and sound notification of information	○	○				
Speech Recognition	Transcribes speech of conversations and calls	○	○	○			
Hearing aid systems	Transmit, receive, and convert speech into audible sound		○				
Writing devices	Message boards, typing, and speech-to-speech, handwritten chat		○				
Telephone-related equipment	Volume amplification, pitch adjustment, and voice transcription		○	○			
PC input-related equipment	Input and operation aids, mouse for feet, and mouth			○			
Environmental conditioning equipment	AT devices for upper limb disabilities, timers for intellectual, and developmental disabilities, partitions and headphones to block stimuli for developmental disabilities, and weighting devices for sensory support for developmental disabilities			○		○	○

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		Type of disability					
		Visual	Hearing	Upper limb	Lower limb	Intellectual	Developmental
Device	Main function						
Others	AT devices for upper limb disabilities, timers for intellectual, and developmental disabilities, partitions and headphones to block stimuli for developmental disabilities, and weighting devices for sensory support for developmental disabilities Input, work support, and recording for the visually impaired; immobilization and grip support for the upper limb impaired; and power wheelchairs and elevating desks for the lower limb impaired.	○		○	○		

Table 1.
Assistive technology devices for employment by disability type (National Institute of vocational rehabilitation).

in **Table 1**[1], in order to present an overall picture of the status of ICT and AT devices for employment. As of January 2021, the page featured devices for six types of disability. Note that devices for psychiatric disorders and higher brain dysfunction are not included.[2]

Here, the primary feature of the disability and its necessary devices will be described. First, for visual impairment, devices related to text-to-speech, magnification of images and text, and input or display of braille have been introduced. Next, for hearing impairment, devices for non-audio notifications, speech-to-text, aiding communication, and adjusting volume and voice have been introduced. For upper limb disability, there is impaired function of the hands or fingers, and devices for speech-to-text without using hands, assisting input using means other than the hands, and aiding holding and gripping have been introduced. In lower limb disability, there is impaired function of the feet or legs, and wheelchairs and height-adjustable desk devices for use in the workplace have been introduced. In intellectual disability, there is impaired cognitive function (e.g., intellectual function), and a timer for self-management of work schedules and other tasks has been introduced. Regarding developmental disability, timers presenting time visually have been introduced for instances involving difficulty in understanding clocks, and devices reducing visual and auditory stimulation have been introduced for sensory hypersensitivity [13].

Some devices can be used in multiple disorders, including "signaling devices" with a notification function, which can be used in visual impairment and hearing impairment; "voice recognition" capable of speech-to-text used in visual impairment, hearing impairment, and upper limb disability; and "phone-related devices" capable of adjusting volume or voice, or speech-to-text, used in hearing impairment and upper limb disability. Among "environmental control devices," weighted chain vests and blankets have been introduced as an aid for physical sensation in people with developmental disorders. However, Ekholm et al. [14] reported that these tools are also effective for people with psychiatric disorders. Thus, when it comes to ICT and AT devices for employment, it is essential to choose the appropriate device considering not only the type of disability but also the challenges that the support recipient needs assistance with.

4. Previous studies regarding ICT and AT devices for employment

4.1 Research trends

4.1.1 Research question and method

This section discusses a literature review conducted to identify trends in research on ICT and AT devices for employment. A systematic review was conducted based on the PRISMA flow diagram.[3] Details of the protocol and a flow chart are shown in **Figure 1**.

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[1] Here in the database, I have organized the equipment presented by each disability in the "Select by Disability" section.

[2] Disability names include higher brain dysfunction, but no devices were listed as of January 7, 2021.

[3] A systematic review is a method of comprehensively collecting, evaluating, and integrating the literature on the scientific evidence of studies relevant to a research subject. The PRISMA (the Preferred Reporting Items for Systematic Reviews and Meta-analyses Statement) flowchart is a graphical representation of the systematic review process. This study followed the PRISMA flowchart procedures to the extent possible.

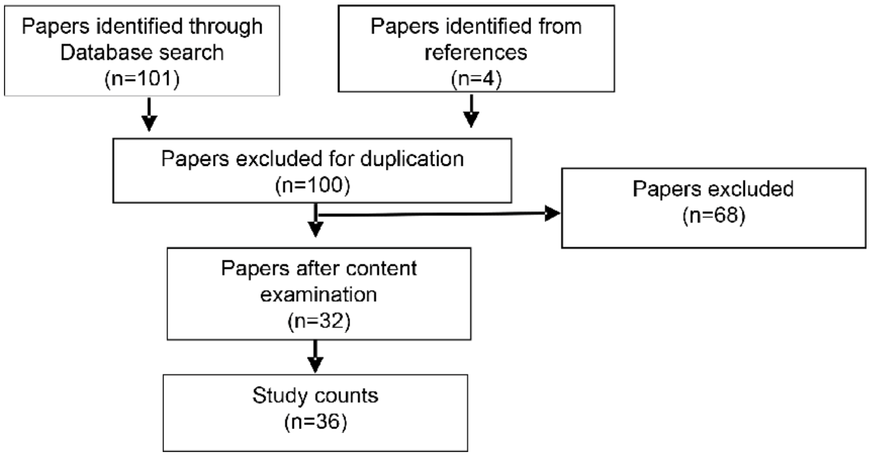

Figure 1.
Procedure of the present study.

4.1.1.1 Database search

4.1.1.1.1 CiNii (National institute of informatics)

Papers were searched using a mixture of terms related to employment, disability, ICT, and AT devices. Search terms were: (employment OR work OR occupation) AND (disability OR disabled) AND (ICT OR information and communication technology OR information device OR tablet device OR smartphone OR cellphone OR assistive technology device OR assistive technology). Note that these terms were searched in Japanese. The search resulted in the selection of 88 papers.

4.1.1.1.2 Organizational chart of studies on vocational rehabilitation (National institute of vocational rehabilitation)

This organizational chart arranges reports from the National Institute of Vocational Rehabilitation using frameworks such as “the relationship with ICF,” and can be used to search reports connected to relevant sub-items [15]. For example, in the present paper, relevant reports were selected from the ICF environmental factor sub-items of “understanding the status of use, needs, etc. of employment assistive technology devices,” “development of employment assistive technology devices,” and participation sub-item “research on understanding the status of diverse workstyles, etc. among people with disabilities.” The search resulted in the selection of 12 papers.

4.1.1.2 Hand search

Relevant papers were identified from the references of the papers selected in A and B above. The search resulted in the selection of four papers.

4.1.1.3 Exclusion criteria and number of papers/studies

First, duplicate papers were excluded. Academic conference abstracts and symposium lecture transcripts were also eliminated from the selected papers. For separate reports or articles that were clearly reporting the same research results, only the most recent study was counted. Subsequently, the selected papers were collected, and articles that did not correspond to the research question were eliminated based on the title, abstract, and main text.[4] This resulted in the selection of 30 papers.

Studies were then extracted from the papers and counted. Each separate objective or method of survey, development, implementation, etc., was, respectively, counted as one study. Thus, a single paper or report sometimes yielded multiple studies. Ultimately, 30 papers containing 36 studies were extracted.

4.1.2 Study counts

The 36 selected studies were classified into the "type of disability" targeted, and "employment support setting (general, consultation/training, expanding range of work, employment, continued employment)" based on the study objective and content. For the classification of employment support settings, those studies that are not limited to specific support settings are classified as "general", those related to pre-employment vocational counseling, learning, and training as "counseling and training", those aiming to expand into new occupations or duties as "expanding range of work", those related to the actual workplace as "employment", and those related to continued employment for those who developed new disabilities during employment as "continued employment". The results are shown in **Table 2**. Looking at the results for the number of studies by type of disability, we found that the most common type was physical disability, with 20 studies. Considering the employment support setting, the most common was employment with 12 studies. However, classifications of disability and employment support settings were made based on the study objective and content in order to understand research trends. In reality, ICT and AT devices could likely be applied to other disabilities and settings depending on the employment challenges and goals of support.

4.1.3 Summary of research content

The content of the selected studies is shown in **Table 3**. Here, surveys, developments, implementations, and secondary analyses have been compiled by employment support setting and summarized.

4.1.3.1 General

Studies concerned with general employment support settings were as follows: Among studies targeting all disabilities, "surveys" included a survey of the actual conditions of ICT use at work support centers for continuous employment type B, which reported the conditions of ICT use in supporting and contacting clients as of 2018, before the impacts

[4] In this study, the author alone was responsible for determining the applicability or non-applicability of the literature.

Employment support setting	General	Consultation/ training	Expanding range of work	Employment	Continued employment	Total
Type of disability						
All Disabilities	3	4	4	—	—	11
Physical disability	2 (Ortho/ visual 1 · Ortho 1)	2 (Ortho 2)	3 (Ortho 1 · visual 2)	12 (Ortho 2 · visual 10)	1 (Visual 1)	20
intellectual disability	—	2	—	—	—	2
Psychiatric disorder	—	—	1	—	—	1
Developmental disability	1	—	—	—	—	1
Higher brain dysfunction	2	—	—	—	—	2
Intractable disease	1	—	—	—	—	1
Multiple disability	—	—	—	2	—	2
Total	9	8	8	14	1	40

**For physical disabilities, a breakdown of the specific disability types has been provided in parentheses if the information was available.*
**Ortho = orthopedic impairment, visual = visual impairment.*

Table 2.
Research papers on ICT and AT devices in vocational rehabilitation.

of COVID-19 [16]. The report found that ICT was used in direct support for "creation of support plans" (69.6%), "creation of support records" (64.0%), "work instruction, etc." (40.2%), "communication" (25.4%), and "leisure" (32.8%). Further, 34.1% of facilities felt that "email should be used in contacting clients" and 19.0% felt that "Social Networking Service (SNS) such as Line should be used in contacting clients"; 32.0% and 16.6% were actually using "email" and "SNS such as Line," respectively, to contact clients. These figures have likely changed drastically since then, considering the current need for online contact and consultation due to COVID-19. Next, there were two "secondary analyses" using the same survey data: a report on the challenges of utilizing assistive products [17] and a report on differences in the actual conditions and possibilities for the use of ICT and AT devices for different disability types [18]. Among studies targeting physical disabilities, "surveys" assessed the need for AT devices for physical disabilities and visual impairments [19], and "developments" included the development of an assistive input function for smartphones regarding physical disabilities [20]. Among studies targeting developmental disabilities, "surveys" included a survey report on the conditions of effective use of time aids supporting time management [21]. Regarding studies targeting higher brain dysfunction, "developments" included the development of a cellphone application supporting task performance [22], and "implementations" included a report on group work for AT use [23].

Setting	Literature	Contents
General	All Disabilities	
	Toyo University Research Center for Development of Welfare Society [16]	[Survey] Online questionnaire survey was conducted to 2400 work support centers for continuous employment type B regarding the actual conditions of ICT use and awareness. (361 centers responded, collection rate of 15.0%). Summarized the status of ICT maintenance, utilization by terminal and purpose, and awareness of ICT utilization
	Jonishi et al., [17]	[Secondary analysis] Secondary analysis of open-ended responses from survey data from Toyo University Research Center for Development of Welfare Society, (2019). Summarized the actual conditions and challenges of ICT utilization.
	Seino et al., [18]	[Secondary analysis] Secondary analysis of survey data from Toyo University Research Center for Development of Welfare Society (2019), including both selective and open-ended responses. Summarized the actual conditions and challenges of ICT utilization by disability type.
	Physical disability (Orthopedic impairment /visual impairment)	
	Sasaki et al., [19]	[Survey] Questionnaire survey of centers regarding job requirements (4131 valid responses, 39.1% response rate). Group interviews with five persons with orthopedic impairment and six persons with visual impairment who use personal computers regarding their needs for the development of AT devices.
	Physical disability (Orthopedic impairment)	
	Miyazaki et al., [20]	[Development] Development of customizable smartphone user interfaces.
	Developmental disability	
	Takezawa et al., [21]	[Survey] Two persons with autism spectrum disorder were lent a Time Aid to assist with time management for trial use, and semi-structured interviews were conducted to investigate environmental adjustments and other conditions that would be useful in employment support situations.
	Higher brain dysfunction	
	Nakayama et al., [22]	[Development] Development of a cellphone application to assist persons with memory impairment, attention disorder, or executive dysfunction. Evaluation in a vocational training assignment. Functions developed were a work procedure display function, a schedule management function, and an alarm function. Conducted a histogram creation task for use in job training for five people with higher brain dysfunction and verified the effectiveness.
	National Institute of Vocational Rehabilitation, [23]	[Implementation] In order to impart knowledge of AT and create opportunities for its utilization, group work on the theme of AT utilization was conducted with five subjects with higher brain dysfunction. In the course of the group work, a questionnaire was conducted on the knowledge of AT and its utilization.
	Intractable disease	
	Haruna, [24]	Theoretical discussion of life functions in amyotrophic lateral sclerosis (ALS). Mentioned the possibility of employment through the use of ICT and AT devices

Setting	Literature	Contents
Consultation/ training	All Disabilities	
	Togasaki, [25]	[Implementation] Implementation by the mailing list CWF-CONSUL to promote employment and case studies of consultations
	Tsuji et al., [26]	[Survey] Questionnaire survey of schools, students, and teachers of special-needs schools in Miyazaki Prefecture and adults with disabilities regarding the actual status of ICT utilization (184 responses, 49.3% collection rate). Summarized challenges in ICT utilization, job hunting, and other issues.
	Shimura et al., [27]	[Implementation] Implemented support using mobile terminals and applications was provided to three users of a multifunctional center that provides employment support, and the effects of ICT utilization were discussed.
	Takezawa et al., [28]	[Development] Development of ITC materials for learning the communication of assertiveness in the workplace. Online, quiz-style learning. Development with the participation of the people with developmental disabilities and the employees of the company to collect their opinions during the development process.
	Physical disability (Orthopedic impairment)	
	Togasaki, [25] (Reprinted)	[Implementation] Simulated at-home training was conducted with three people with physical disabilities in order to clarify the environmental conditions necessary for at-home training
	Tsuji et al., [26] (Reprinted)	[Development] Development of an e-learning educational support system for learning business software.
	Intellectual disability	
	Osugi et al., [29]	[Development] [Implementation] Developed a cell phone web bulletin board for learning about vocational life and social independence on a network. Trials were conducted with five people with disabilities (graduates of special-needs schools) who are working and five students from the upper secondary school of special-needs schools.
	Koizumi et al., [30]	[Secondary analysis] Secondary analysis of survey data from Toyo University Research Center for Development of Welfare Society (2019). Summarized the use of tablet devices in work support centers for continuous employment type B that support people with intellectual disabilities.

Setting	Literature	Contents
Expanding range of work	All Disabilities	
	Takano, [31]	The actual conditions of 17 work from home support groups are summarized from the literature, and the problems of the support system for people with disabilities working from home are discussed.
	Takano, [32]	[Survey] Interviews were conducted with 13 work from home support groups, and the groups were categorized into three types: "business-oriented," "party-established," and "support-oriented.
	Yamaoka et al., [33]	[Survey] Questionnaire survey of 107 work support centers for persons with disabilities (support for transition to employment, support for continuous employment A and B, etc.) that conduct work using personal computers (50 centers responded, 46.7% response rate). Examined the possibility of work using ICT and working from home.
	Yamaoka et al., [34]	[Survey] Analyzed the results of Yamaoka et al.'s [33] questionnaire survey of work support centers for people with disabilities that conduct work using computers. Interview survey of six work support centers for persons with disabilities. Examined the possibility of work using ICT and work from home.
	Physical disability (Orthopedic impairment)	
	Okada et al., [35]	[Development] Development of large and small special keyboards for people with upper limb disabilities.
	Physical disability (visual impairment)	
	Igarashi et al., [36]	[Survey] Survey of character layout in schools for the visually impaired and classes with low vision in elementary schools for the development of magnification materials (number of respondents: 206 with horizontal writing).
	Okada et al., [37]	[Development] Prototype of Windows screen reading software. Trial evaluation by 51 people with visual impairments.
	Psychiatric disorder	
	Yamaoka, [38]	[Survey] Interviews were conducted with two companies introducing work from home programs for persons with psychiatric disorders. Summarized the actual conditions of telework and ICT use for people with psychiatric disorders and the challenges they face.

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Setting	Literature	Contents
Employment	Physical disability (Orthopedic impairment)	
	Sakajiri et al., [39]	[Survey] Group interview survey of six people with lower limb disabilities about their wheelchair needs in work situations, questionnaire survey of 17 indoor wheelchair users, etc.
	Sakajiri et al., [39] (Reprinted)	[Development] Development of an office wheelchair for people with lower limb disabilities. Driving tests and evaluation
	Physical disability (visual impairment)	
	Okada et al. [40]	Summarize ICT and assistive devices that can be used by the people with visual impairments in work situations.
	Okada et al. [41]	[Survey] Questionnaire survey of people with low vision on the use of magnifying devices for reading (115 cases collected from 109 people)
	Okada et al. [41](Reprinted)	[Development] Prototype of a compact and lightweight magnifying device for reading. Trial evaluation by three people with low vision
	Watanabe et al., [42]	[Survey] Questionnaire survey on the use of Windows PCs among the people with visual impairments (81 respondents)
	Watanabe et al., [43]	[Development] Development of a tactile mouse with a small tactile display
	Watanabe et al., [43] (Reprinted)	[Development] Development of a two-dimensional tactile display system。
	Okada, [44]	[Development] Development of a space-saving magnifying device for reading.
	Okada, [44] (Reprinted)	[Development] Development of a portable on-premises magnifying device for reading
	Okada [45]	[Survey] Questionnaire survey of 33 persons with low vision regarding their use of assistive devices and their needs for improvement, including interviews with 12 of them
	Multiple disability(hearing disability/visual impairment)	
	Sakajiri et al., [46]	[Development] Development of finger Braille support systems for communication.
	Sakajiri et al., [46] (Reprinted)	[Development] Development of a tactile display system for kana display for people with hearing and visual impairment who have not mastered Braille
Continued employment	Physical disability (visual impairment)	
	Okada et al., [40] (Reprinted)	Summarize training items and ICT/assistive devices used for vocational training for continued employment of people with intermediate visual impairment.

**At the start of each content description, the study method has been provided in brackets as "development," "survey," "implementation," or "secondary analysis." Unlabeled studies are either literature surveys or theoretical discussions.*

Table 3.
Content of studies on ICT and AT devices for employment support.

4.1.3.2 Consultation/training

Studies concerned with consultation/training settings were as follows: Among studies targeting all disabilities, "surveys" included a survey of the actual conditions of ICT use [26], "developments" included the development of teaching materials for learning workplace communication online [28], and "implementations" included consultation using a mailing list [25]) and support using an iPad and an application [27]. Among studies targeting physical disabilities, "developments" included the development of an e-learning system for physical disabilities [26], and "implementations" included a report on at-home training courses for physical disabilities [25]. Regarding studies targeting intellectual disabilities, "developments" and "implementations" included the development and implementation of a web bulletin board for learning support [29], and "secondary analyses" included the introduction of devices at welfare centers [30]. Of these studies, those concerning online consultation/training will be particularly helpful as tools aiding remote support. Moreover, given the likelihood that remote support needs will persist and grow going forward, further development and validation of the effectiveness of such systems and tools enabling remote consultation and learning for people with disabilities are expected in the future.

4.1.3.3 Expanding range of work

Studies concerned with expanding the range of work settings were as follows: Among studies targeting all disabilities, "surveys" included surveys of the actual conditions of work from home support groups [32] and of work support centers conducting operations using personal computers [33, 34]. Next, among studies targeting physical disabilities, "surveys" included a survey of character layouts for the development of teaching materials for visual impairments [36], and "developments" included the development of a keyboard for upper limb disabilities [35] and screen reading software for visual impairments [37]. Among studies targeting psychiatric disorders, "surveys" included a survey of the actual conditions of telework and ICT use [38].

4.1.3.4 Employment

Studies concerned with employment settings were as follows: Among studies targeting physical disabilities, "surveys" included surveys of the wheelchair needs in physical disabilities [39], the status of use of magnifying devices for reading regarding visual impairments [41], personal computer use [42], and the status of use and improvement needs for devices [45]; "developments" included the development of an office-use wheelchair for physical disabilities [39] a magnifying device for reading for visual impairments [41, 44], a tactile mouse and tactile display [43], and finger braille support and a tactile display for people with both hearing and visual impairments [46].

4.1.4 Summary of research trends

Looking at past studies by disability type, most were on the development of AT devices without communication functions for people with physical disabilities. Potential reasons for this include that, in the narrow sense, "AT devices" refer to assistive devices such as artificial limbs for people with physical disabilities, and that the functional impairments of physical disabilities tend to match the characteristics of devices that support or replace the function in terms of suitability. However, considering the current growing need for remote support and telework, the accumulation of more research on the use and application of ICT and AT devices for other types of disabilities can be expected in the future. One helpful example of this is SPIS (Supporting People to Improve Stability), a support system helping people with psychiatric disorders and developmental disabilities keep their jobs [47]. According to the SPIS Research Institute [47], SPIS is a daily report system that monitors mood, physical condition, work, and interactions with others used for work management and self-monitoring. This kind of system can also be considered an ICT and AT device. With the current decline in opportunities to meet face-to-face with others due to the transition to telework, tools that can be managed remotely, like SPIS, are likely to be particularly effective.

Although it was not addressed in this review, it is quite possible that ordinary device functions and general applications unrelated to disabilities are being used by people with disabilities for employment purposes. In other words, devices that were not developed specifically for people with disabilities or employment may be used for employment purposes. As these devices are not new, they get little research coverage, but gathering information and ideas for the use of such devices through implementation reports and sharing usage examples may be useful for providing support.

4.1.5 Expectations for development

This review included survey, development, implementation, and other study methods, but the most distinctive was development. Research on conventional support includes the development of teaching materials and programs, but the development of technology and products, including cutting-edge engineering techniques, are a unique feature of studies of ICT and AT devices. Specifically, the participation of future users in the development process, as taken by Takezawa et al. [28], and multidisciplinary collaborative research and development in which interpersonal support professionals from the fields of welfare and medicine collaborate with engineering researchers are likely to be effective.

5. Conclusion

This paper first presented a basic framework of approaches to ICT and AT devices for employment, clarified the status of such devices in Japan, and identified research trends. At present, a good amount of information on implementation and research on ICT and AT devices for employment has been collected. However, the following three issues are challenges to be addressed in the future: First, the scope of ICT and AT devices for employment is not clear. Second, there is a dearth of research on AT devices for non-physical disabilities. Third, many of the studies are reported as bulletins and implementation reports; there has been little validation through scientific research. The efforts described below may be effective in resolving these challenges. Regarding the first challenge, the findings on ICT and AT devices necessary for everyday and professional life (e.g., mobility), in settings other than those directly related to employment (e.g., training, work duties), should be comprehensively compiled. For the second challenge, as Shiruma et al. [27] suggest, findings from the field of special education in which the use of ICT and AT devices such as tablets is particularly advanced should be referenced. Moreover, ICT and AT devices for employment should be viewed more widely, including self-care and stress monitoring tools like the SPIS system for psychiatric disorders described above, not just tools compensating for functional disabilities. Concerning the third challenge, practical, scientific research with participation and implementation by people with disabilities should be promoted. The increase in telework and remote work accompanying the COVID-19 pandemic has led to a greater need to use ICT and AT devices to perform duties, manage work, and support and contact clients, thereby accelerating its use. The accumulation of further research and implementation initiatives is hoped to improve the effectiveness of ICT and AT device applications in the future.

Future prospects include the potential to facilitate employment and an expanded range of work for people with disabilities through both the effective use of existing technologies and products, and the development of new technologies and products. Furthermore, when developing new ICT and AT devices, it will likely be effective to promote collaboration with multidisciplinary professionals and participation by people with disabilities in research and development, as has been highlighted in recent years.

The following are two limitations of the present paper: First, since the paper dealt only with previous studies on employment of people with disabilities, it did not consider general devices unrelated to disabilities or settings outside of training and work. Second, the organization of devices focused on disability types and employment settings, and therefore did not compile devices from other perspectives, such as type of difficulty or disability severity. These are challenges for future research.

It is hoped that the response to COVID-19 will be used as an opportunity for those involved in employment support to take a fresh look at how ICT and AT devices should be used for employment, thereby contributing to the realization of better professional lives.

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Conflict of interest

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References

[1] Ministry of Internal Affairs and Communications. Information and Communication White Paper 2020 (in Japanese). Ministry of Internal Affairs and Communications [Internet]. 2020 [cited 2021 Jan 07]. Available from: https://www.soumu.go.jp/johotsusintokei/whitepaper/ja/r02/pdf/02honpen.pdf/

[2] Apple. Support for Accessibility (in Japanese). Apple [Internet]. [cited 2021 Jan 07]. Available from: https://support.apple.com/ja-jp/accessibility/

[3] Vector, Inc. UD Talk. Vector, Inc. [Internet]. 2015 [cited 2021 Jan 07]. Available from: https://udtalk.jp/

[4] Persol Challenge Co. Ltd. News Release "Survey Results on the Impact of COVID-19" (in Japanese) [Internet]. PERSOL Challenge. 2020 [cited 2021 Jan 07]. Available from: https://challenge.persol-group.co.jp/wp-content/uploads/2020/07/news_6400-1.pdf

[5] Genka M. Current Status and Future of Employment for People with Disabilities Focusing on response to COVID-19 (in Japanese). The Nippon Foundation Employment Support Forum NIPPON Online [Internet]. 2020 [cited 2021 Jan 07]. Available from: https://hataraku-nippon.jp/forum-online/dl/sfn_online_mhlw_20200824.pdf

[6] Ministry of Health, Labour and Welfare. 100th Labor Policy Council Group Discussion for Employment of Persons with disabilities -Document 2-2: Outline of Major Issues and Future Directions for Consideration Toward Further Enhancement and Strengthening of Employment Support for Persons with Disabilities (Interim Summary) (in Japanese). Ministry of Health, Labour and Welfare [Internet]. 2020 [cited 2021 Jan 07]. Available from: https://www.mhlw.go.jp/content/11704000/000683315.pdf

[7] Ministry of Health, Labour and Welfare. 102nd Labor Policy Council Group Discussion for Employment of Persons with disabilities – Reference Materials 3-5: Main opinions at the 1st Joint Study Meeting (in Japanese). Ministry of Health, Labour and Welfare [Internet]. 2020 [cited 2021 Jan 07]. Available from: https://www.mhlw.go.jp/content/11704000/000709512.pdf

[8] United States Government. Technology-Related Assistance for Individuals With Disabilities Act of 1988. Congress.gov [Internet]. 1988 [cited 2021 Jan 07]. Available from: https://www.congress.gov/bill/100th-congress/senate-bill/2561

[9] Munekata T. Definition of Assistive Technology - Part 1: From IDEA in the U.S. (in Japanese). National Institute of Special Needs Education [Internet]. 2012 [cited 2021 Jan 07]. Available from: http://www.nise.go.jp/cms/6,6205,13,257.html

[10] World Health Organization. Study group for the development of the international classification of disabilities (Translated) (in Japanese). In: International Classification of Functioning, Disability and Health (ICF)- Revised International Classification of Disability. Tokyo, Japan: Chuohoki Publishing CO., Ltd.; 2002

[11] Inoue T. Challenges and prospects as welfare devices (in Japanese). Normalization Welfare for Persons with Disabilities. 2015;**35**(4):14-17

[12] Nakayama T. NRCD Web News: Report on participation in the International Organization for Standardization International Meeting (ISO TC 173/SC 2/WG 12). National

Rehabilitation Center for Persons with Disabilities [Internet]. 2012 [Accessed: January 7, 2021]. Available from: http://www.rehab.go.jp/rehanews/japanese/webnews/201210/news_201210_3.html

[13] National Institute of Vocational Rehabilitation. Resources for Job-related Assistive Technology. Japan Organization for Employment of the Elderly, Persons with Disabilities and Job Seekers [Internet]. 2019 [cited 2021 Jan 07]. Available from: https://www.kiki.jeed.go.jp/index.html

[14] Ekholm B, Spulber S, Adler M. A randomized controlled study of weighted chain blankets for insomnia in psychiatric disorders. Journal of Clinical Sleep Medicine. 2020;**16**(9):1567-1577

[15] National Institute of Vocational Rehabilitation. Research System Chart (in Japanese). Japan Organization for Employment of the Elderly, Persons with Disabilities and Job Seekers [Internet]. [cited 2021 Jan 07]. Available from: https://www.nivr.jeed.go.jp/research/chart/index.html

[16] Toyo University Research Center for Development of Welfare Society. Report on the Results of a Survey on the Actual Status and Awareness of ICT Use among Providers of Work Support for Continuous Employment Type B Services. (in Japanese). Tokyo, Japan: Toyo University Research Center for Development of Welfare Society; 2019

[17] Jonishi K, Mochizuki T. Difficulties associated with the use of ICT by persons with disabilities: An analysis of open-ended statements in a national survey at work support centers for continuous employment type B. (in Japanese). Annual Report of Researches on Development of Welfare Society. 2020;**12**:51-60

[18] Seino K, Maruyama A. Actual conditions and possibilities of ICT utilization among providers of support for continuous employment support type B services: Comparison of disability types of psychiatric, intellectual, and physical disabilities (in Japanese). Annual Report of Researches on Development of Welfare Society. 2020;**12**:37-50

[19] Sasaki M, Okada S, Yatogo T, Nonaka Y. Development of comprehensive work support technology for persons with severe disabilities - No. 1. In: National Institute of Vocational Rehabilitation Research Reports 7. Chiba, Japan: National Institute of Vocational Rehabilitation; 1995

[20] Miyazaki E, Sakai S, Taniguchi K, Noda T, Oono K, Shinohara T. The trial production of the disabled person input auxiliary device for smart phones. Memoirs of the Faculty of Education Kagawa University Part II. 2012;**62**(2):75-83

[21] Takezawa T, Enomoto Y, Ishiwata R, Mizumura S, Inoue T. Case report of job assistance for persons with autism Spectrum disorder by using a time-aid. Journal of the Society of Plant Engineers Japan. 2017;**28**(4):160-163

[22] Nakayama T, Miyaji Y, Kato S, Sakurada N, Ueda N, Nomura T, et al. Mobile phone application for supporting persons with higher brain dysfunctions. The Transactions of the Institute of Electrical Engineers of Japan. C. A publication of Electronics, Information and Systems Society. 2010;**130**(3):394-400

[23] National Institute of Vocational Rehabilitation. Employment supports utilizing assistive technology for people with higher brain dysfunction. In: National Institute of Vocational Rehabilitation Practice Reports, 35. Chiba, Japan: National Institute of Vocational Rehabilitation; 2020

[24] Haruna Y. Functioning of persons with ALS. The Japanese

Journal of Rehabilitation Medicine. 2018;**55**(7):551-555

[25] Togasaki F. Study on the utilization of the internet for the promotion of employing persons with disabilities, mainly of home-based workers (February 1999). In: National Institute of Vocational Rehabilitation Research Report, 35. Chiba, Japan: National Institute of Vocational Rehabilitation; 1999

[26] Tsuji T, Tasaki Y, Nozawa Y. Development of effective e-learning education support system for handicapped person. Bulletin of Miyazaki Municipal University Faculty of Humanities. 2009;**16**(1):175-189

[27] Shimura K, Seino K, Miyatake T, Araki K, Koizumi T, Sangu N. ICT use in welfare facilities for persons with disabilities (in Japanese). Annual Report of Researches on Development of Welfare Society. 2015;**7**:33-45

[28] Takezawa T, Enomoto Y, Ogoshi S, Ogoshi Y, Kobayashi S, Nambu J, et al. Development of ICT teaching materials for communication in the office. Journal of the Society of Plant Engineers Japan. 2018;**30**(2):55-59

[29] Osugi N, Kimura M, Mikawa K, Kuroda Y. Transition support with web site of cellular phone on special support education. Memoirs of the Faculty of Education. Shiga University. Pedagogic science. 2008;**58**:111-122

[30] Koizumi T, Kiguchi E, Maruyama A. A study on the use of tablets in work support centers for continuous employment type B: Focusing on centers whose main users are the persons with intellectual disabilities (in Japanese). Annual Report of Researches on Development of Welfare Society. 2020;**12**:61-67

[31] Takano T. Job support to the challenged and home work. The Bulletin of Department of Health and Social Services. Hiroshima International University. 2012;**8**:1-19

[32] Takano T. Actual situation and problems of home work support groups: The case of home teleworker with disabilities. The Bulletin of Department of Health and Social Services. Hiroshima International University. 2014;**10**:41-59

[33] Yamaoka Y, Takada R. Possibility of providing more job opportunities and chances of stay-home works for the person with disabilities in Tohoku area by utilizing ICT (information and communication technology): Based on the results of examination conducted on employment support services for the person with disabilities and other relevant services. Bulletin of the Faculty of Social Welfare. Iwate Prefectural University. 2018;**20**:37-46

[34] Yamaoka Y, Takada R. The possibilities of working from home and jobs utilizing information and communications technology (ICT) for people with disabilities in Tohoku region: Based on surveys conducted by the employment support Office for People with disabilities and other organizations in Tohoku region, Chugoku region, and Shikoku region. Bulletin of the Faculty of Social Welfare. Iwate Prefectural University. 2019;**21**:75-85

[35] Okada S, Oku H, Booka M, Obata J, Aikawa T, Hatakeyama T. Development of comprehensive work support technology for expanding the occupational field for persons with severe disabilities – No. 4. In: Development of Large-Sized/Small-Sized Specially Designed Keyboards for Persons with Upper Limb Impairment. National Institute of Vocational Rehabilitation Research Report, 23. Chiba, Japan: National Institute of Vocational Rehabilitation; 1998

[36] Igarashi N, Kagawa K, Kakizawa T, Goryo K, Sashima T, et al. Reading for

visually impaired persons and clerical occupations. In: National Institute of Vocational Rehabilitation Research Report, 2. Chiba, Japan: National Institute of Vocational Rehabilitation; 1993

[37] Okada S, Yatogo T, Watanabe T. Development of comprehensive work support technology for persons with severe disabilities - No. 2. In: National Institute of Vocational Rehabilitation Research Reports, 16. Chiba, Japan: National Institute of Vocational Rehabilitation; 1996

[38] Yamaoka Y. Analysis of promoting factors for telework for people with mental disabilities: Through the hearing cases of corporations. Bulletin of the Faculty of Social Welfare. Iwate Prefectural University. 2015;**17**:11-20

[39] Sakajiri M, Ogino S, Hirose H, Kinose T, Kawai T, Tl S. Development of comprehensive work support technology for expanding the occupational field for persons with severe disabilities - No. 5. In: Development of an Office Wheelchair for Persons with Lower Limb Impairment. National Institute of Vocational Rehabilitation Research Reports, 24. Chiba, Japan: National Institute of Vocational Rehabilitation; 1998

[40] Okada S, Nakamura T, Watanabe F, Kitabayashi Y, Aoki S, Watanabe T. Continued employment of persons with adventitious visual impairment and utilization of support devices. In: National Institute of Vocational Rehabilitation Research Reports, 18. Chiba, Japan: National Institute of Vocational Rehabilitation; 1997

[41] Okada S, Watanabe T, Sakajiri M. Use of magnification reader aid for visually-impaired persons and the improvement needs - report of "study on workplace improvement with regard to persons with severe visual impairment". In: National Institute of Vocational Rehabilitation Research Reports, 40. Chiba, Japan: National Institute of Vocational Rehabilitation; 2000

[42] Watanabe T. User survey on windows PCs by persons with visual disabilities. In: National Institute of Vocational Rehabilitation Material Series, 22. Chiba, Japan: National Institute of Vocational Rehabilitation; 2001a

[43] Watanabe T, Sugai K, Tamechika T. Study on the haptic display system for presenting graphical information. In: National Institute of Vocational Rehabilitation Research Reports, 41. Chiba, Japan: National Institute of Vocational Rehabilitation; 2001b

[44] Okada S. Development of magnification reader aid based on user needs - study on the development of magnification reader aid for persons with adventitious visual impairment. In: National Institute of Vocational Rehabilitation Research Reports, 51. Chiba, Japan: National Institute of Vocational Rehabilitation; 2002

[45] Okada S. Usage situation and improvement of assistive technology for employment of persons with low vision. In: National Institute of Vocational Rehabilitation Material Series, 65. Chiba, Japan: National Institute of Vocational Rehabilitation; 2012

[46] Sakajiri M, Mizuho Y. Study on communication aids for supporting persons with multiple disabilities of vision and hearing at work. In: National Institute of Vocational Rehabilitation Research Reports, 46. Chiba, Japan: National Institute of Vocational Rehabilitation; 2002

[47] SPIS Institute, Inc. Support System for the Establishment of Employment: SPIS (Supporting People to Improve Stability) (in Japanese). Tokyo, Japan: SPIS Institute, Inc; 2015 [Internet]. [cited 2021 Jan 07]. Available from: https://www.spis.jp/laboratory/about.html#houjin

Chapter 5

Perspective Chapter: Assistive Technology Ecosystem for Effective Self-Care – Application to Alzheimer's and Related Dementia

Helen H. Chen, Meenu Sikand, Ying Zhu and Zeeyaan Bourdeau

Abstract

People living with Alzheimer's disease and related dementias (PwADRD) experience declined memory, language, problem-solving and other cognitive functions caused by the disease. They face major challenges in self-care and assistive living, including equitable access to assistive technology and care, the right to choose where to live, protection of privacy and security, and the preserving their personhood and social connections. Fast advances in telecommunication, Internet of Things (IoT) technology, and artificial intelligence make it possible to devise an assistive technology ecosystem to address these challenges. This chapter presents an assistive technology ecosystem that enables autonomy, independence and interdependence among PwADRD, their circle of care and society. Participatory action research and design methodology underpin this ecosystem's design and implementation. We also discuss funding policy and health system changes needed to facilitate the affordability and sustainability of such an ecosystem and, ultimately, to empower PwADRD and their caregivers to have a meaningful quality of life.

Keywords: assistive technology ecosystem, people living with Alzheimer's disease, dementia, participatory action research design, self-care, independent living, interdependence, IoT, artificial intelligence

1. Introduction

Alzheimer's disease and related dementia (ADRD) is an acquired cognitive disorder that causes a person's progressive decline in memory, language, learning, problem-solving and other cognitive skills [1]. Alzheimer's disease is the leading cause of dementia, with a larger prevalence in women and older adults - 72% of people with Alzheimer's are projected to be women by 2030; most individuals who are diagnosed with ADRD are 65 or older, and after the age of 65, the risk of ADRD doubles every 5 years, reaching nearly one-third at age 85 [2]. According to the World Health Organization, approximately 55 million people around the world currently live with dementia. In 2022, 10 million new cases of dementia were reported around the world [1]. In Canada, approximately 570,000 people over the age of 65 currently live with dementia. In addition, approximately 124,000 people were recently diagnosed with the syndrome [2]. These numbers are rising sharply owing to increased life expectancy globally as well as earlier diagnoses. In 2015, about 15% of Canadians were 65 or older; and by 2030, one in four Canadians will be an older adult [3]. This translates into an unprecedented number of people living with ADRD (PwADRD) with a relatively small number of people to support them.

PwADRD experiences a progressive decline in cognitive functions and sudden changes in mood and behavior. These changes affect a person's ability to perform everyday activities. PwADRD experience challenges with self-care, limiting their ability to perform or complete activities of daily living themselves. This led to additional caregiving demands on family members and personal care workers who provide care and support for those living in their own homes or congregate settings. As of 2020, ADRD is among the top four diseases from the standpoint of global healthcare pressure points and is anticipated to be in the top three by 2030 [4]. In Canada, a recent study estimates that the combined Canadian healthcare costs and out-of-pocket caregiver costs from ADRD amounted to $10.4 billion in 2016; by 2031, this Figure is expected to increase to $16.6 billion [4]. The alternative of living in a residential facility is both very costly and unsustainable, which can expose PwADRD to severe health risks (as exemplified in the COVID-19 pandemic). In Ontario, the cost of memory care (a facility providing specialized care for those living with dementia) is $4000–$6500 per month per person [5]. There is a first-ever Canadian Dementia Strategy in Canada that has called for a shift to provide integrated community-based care as the primary means of supporting PwADRD and their care partners in Canada [6]. However, for a community-based system to be successful, the health and well-being of both PwADRD and their care partners must be properly supported [7].

Technological advances make it possible to devise an IoT ecosystem to address self-care-related challenges while simultaneously improving the quality of life of PwADRD and their care partners and mitigating the global economic burden [6, 8]. While some disparate IoT solutions have been developed across the globe by research groups such as those associated with the Active Assisted Living (AAL) Programme (http://www.aal-europe.eu/) and AGE-WELL (https://agewell-nce.ca/), a single ecosystem that can support the implementation of assistive technologies at scale is still lacking for PwADRD in their chosen dwelling, particularly at their own home. Furthermore, interoperability, data-sharing, and privacy and security are identified as major challenges in AAL.

2. The voice of the users – participatory action design methodology

Participatory Action Research is an innovative research design which can be implemented when developing resources for PwADRD. The qualitative research methodology is collaborative between researchers and participants [9]. This approach is effective in addressing stigma related to dementia by engaging members of the community to take action and inspire and empower social change [10]. A participatory design implements a community-based approach to planning and executing research studies. The partnership between the researchers and the community is essential when experimenting with assistive technologies for use by individuals with dementia. Tierson and colleagues found that implementing a participatory action research design enhanced their understanding of the experiences lived by PwADRD [11]. Furthermore, Goeman et al. found that the researchers benefitted from the high level of social interactions with PwADRD [12]. Through this engagement, the researchers developed greater insights into the needs of PwADRD and their caregivers. The studies demonstrate that the inclusion of PwADRD enabled researchers to receive first-hand, instantaneous feedback from the stakeholders who would benefit from their findings. Hence, this research approach leads to input from PwADRD based on their real-life experiences using the technologies. Overall, it facilitates the development of more effective products and services for PwADRD.

When developing participatory designs, it is important to recognize the challenges faced by researchers when considering the progressive cognitive decline experienced by PwADRD. Researchers may also experience challenges building strong relationships with the local community [13]. In addition, there is also a level of difficulty experienced by PwADRD in communicating feedback on the pilot technology. This may pose an additional challenge for the researcher in identifying potential user needs. However, best practices can be implemented to mitigate these challenges. Using a community-based approach, researchers may consider incorporating innovations such as AI technologies or personas to assist PwADRD in communicating their feedback. An additional example may include visual aids to help create familiar environments and enhance an individual's ability to recall past events. These approaches demonstrate the inclusive nature of participatory design when experimenting with assistive technologies [14]. This research approach leads to a strengthened network between PwADRD, researchers, and technology developers.

3. Independence and interdependence in active assistive living

In this section, we argue that health can only be understood in a relational context. Robinson Crusoe, living alone on his desert island, might have the most desirable and healthy physique. However, his loneliness and lack of human interaction meant he was healthy in only the narrowest sense. Human identity is found in our relationship with others, from the beginning to the end and beyond – in the memories we have and other legacies we leave. The division between 'you' and 'me' in these caring relationships becomes diminished. The vulnerability of one becomes the vulnerability of others; the disability of the one becomes the disability of the other [15]. The definition of independence by the healthcare system focuses on individuals and an individual's performance capacity [16]. While the independence of PwADRD is an important and measurable outcome of any intervention, we also argue that Assistive Technology (AT) should focus on advancing the interdependence of people with disabilities. This has been challenged by activists and scholars within and outside the AT community [17]. There is increasing recognition of the importance of social and cultural factors in AT use and growing evidence that social relationships can enable PwADRD to lead meaningful lives and improve the well-being of their caregivers [17, 18]. Therefore, "independence" is no longer suffice as the primary goal of AT design. Researchers have proposed approaching AT design through a comprehensive holistic lens, considering individuals' autonomy, independence, and interdependence in the AT ecosystem [17].

Autonomy describes one's ability to make decisions on behalf of self and refers to one's individuality, dignity, integrity, responsivity, and self-knowledge [16]. Autonomy as a human right is considered a fundamental ethical principle of healthcare and is generally valued by the individual [19]. Autonomy does not stop at the individual level, as one's choices are influenced by their development, family and social networks, and spirituality [16]. Recent research has also shown the importance of autonomy to PwADRD with increasing self-advocacy for participation and choice in decisions regarding their care [19]. Independence describes one's ability to perform tasks and activities and is often a key goal for healthcare interventions in Western culture [19]. This emphasis on independence places value on self-reliance, discouraging individuals from reaching out to others for help, which in some cases, can be a key factor in allowing individuals to stay within their homes and communities. Interdependence is the interconnectivity of individuals with each other and with their environments. Lindemann suggests that interdependence is a natural part of community living: "*Colleagues, professional staff members, and other adults are unconscious of the numerous accommodations that society provides to make their work and lifestyle possible. ATM's, extended hours in banks, shopping centres and medical offices, EZpass, newspaper kiosks, and elevators are all accommodations that make contemporary working life possible. There are entire industries devoted to accommodating the needs of adult working people. Fast food, office lunch delivery, daytime child care, respite care, car washing, personal care attendants, interpreters, house cleaning, and yard and lawn services are all occupations that provide services that make it possible for adults to hold full-time jobs*" [20]. Independence and interdependence are complementary concepts. By taking into consideration the fundamental importance of autonomy, independence, interdependence, and health as a relational concept, AT design can be more intentional when considering the impact of social interactions, the role of cultural norms, as well as the contributions of those impacted by AT use.

The latest research suggests that interdependence can create new opportunities in AT research and development in crowd work, ability-based design, and navigation [17]. An interdependence lens can also expand ability-based design and navigation research by incorporating features that adapt to different social contexts and relations. It allows people to reduce the barriers created by their disabilities through collaboration with others and by relying on each other's strengths. By employing the participatory action methodology introduced in the previous section, AT design pays attention to the relations between people and technologies, individuals' dual roles as recipients and contributors to AT and systemic bias. Participatory action methodology sheds light on the transient nature of interdependence and the fluid nature of disability [14]. By understanding that accessibility depends on factors specific to a situation, AT design can account for individual experiences and uncover a broader range of influential factors. The traditional view of people with disabilities as only recipients of support constantly undervalues their contribution to the advancement of accessibility for all. Interdependence encourages researchers and developers to assess relations between people without AT to identify potential biases and support more meaningful access. For example, observations of how blind and sighted partners navigated new environments revealed challenges due to navigation research informed by misconceptions of blind navigation held by sighted people. Additionally, interdependence suggests the possibility of simultaneous relations influencing the accessibility of a particular situation, where people receiving access may also be providing it. By viewing access as an ongoing process where people offer and receive access from each other, AT design can better understand the duality of each participant's role. Interdependence considers all participants being mutually reliant, thus bringing our focus to engaging people with disabilities to co-create accessibility solutions. In addition, society has traditionally considered the actions and contributions of people with disabilities as less important. It fails to recognize the efforts required to navigate complex insurance and funding programs and specialized technology interfaces. Interdependence addresses the systemic undermining of people with disabilities by assuming all participants as crucial to the relationship, resulting in designs that challenge ability-based hierarchies. For example, Incloodle features a cooperative photography application that supports equal participation of neuro-typical and neuro-divergent children [21].

The following section presents an IoT ecosystem that enables active assistive living for PwADRD. Autonomy, independence and interdependence are the underlining principles of this ecosystem.

4. Active assistive living IoT ecosystem

Currently, the state-of-the-art in care for PwADRD involves self-care with the support of care partners who may be: (i) healthcare support workers either at home or in an assisted living facility; or (ii) family and friends. In both cases, there are opportunities to use AT to support autonomy, independence and interdependence, provide a better quality of life and control rapidly increasing costs. Although there are integrated digital solutions at major urban research hospitals for post-operative care, and multiple apps for self-care, there are no ecosystem solutions that are secure, energy-efficient and user-friendly for most Canadians with self-care needs.

We propose a first-of-its-kind suite of IoT devices and associated ecosystems optimized to support the independence of PwADRD. The system, as conceived, supports PwADRD in current best practices such as: "*Eat properly*," "*Exercise*," "*Rest when you are tired*," "*Take medications as prescribed*," "*Stay connected to family members and friends*," "*Live in the moment, appreciating the small joys of life, such as seeing flowers coming into bloom and watching birds at a feeder*", "*Do one thing at a time*," "*Write things down*," "*Follow a routine*," "*Use a dispenser for pills*," and "*Set the timer when using the stove or oven*." [22]. **Figure 1** illustrates the key features of the system. As indicated, a suite of Internet of Things (IoT) devices can: (a) listen/sense, (b) record, (c) learn, and (d) provide feedback that promotes engagement in the above kinds of best practices in self-care. The ecosystem aims to move from existing environments where individual devices are deployed to an integrated, adaptive environment with the potential for linking information with the healthcare system. While the introduction and use of such technology clearly have transformational promise, both from the standpoint of quality of life and economic savings, we must guard against inherent technical limitations.

4.1 IoT ecosystem and integration

A key challenge with a person-centric technology is that it often requires custom deployment for individuals. This makes the ecosystem static and unable to adapt to disease progression or a person's changing circumstances. An PwADRD can go through several transitions as the condition progresses, experiencing mild decline early on to more severe challenges later in the disease trajectory. The

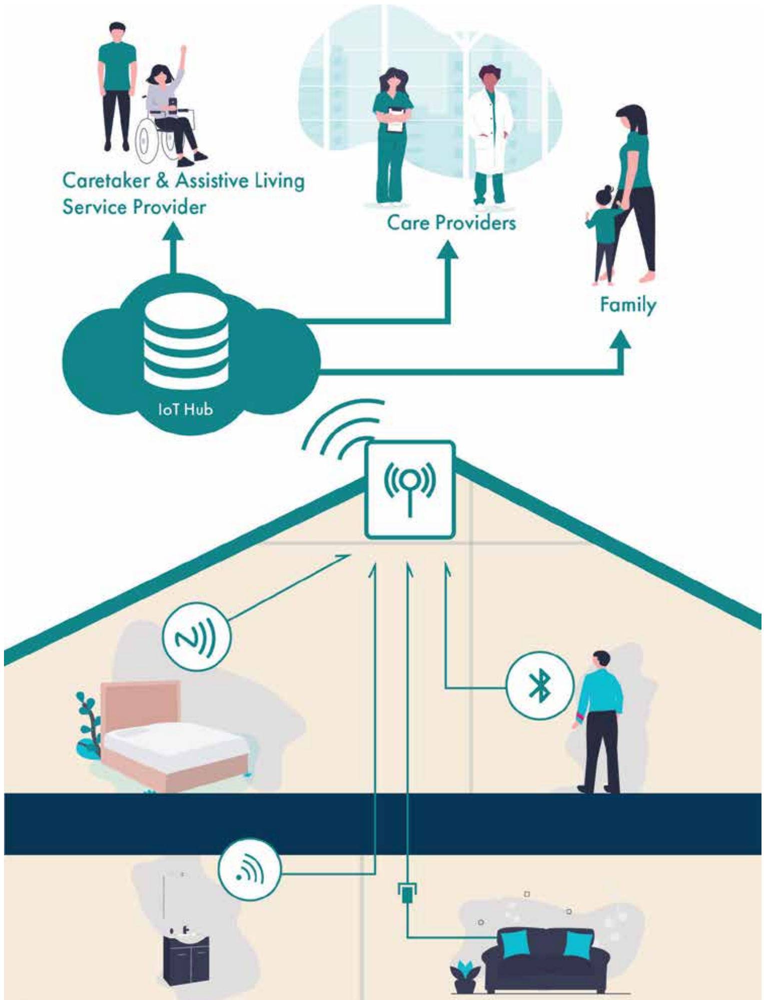

Figure 1.
IoT ecosystem enabling self-care.

individual can also experience day-to-day and even within—day variations in symptoms. The proposed ecosystem seeks to address this explicitly by providing the capability to continuously learn the progression of the disease and adapt and extend mechanisms to address concerns in a non-intrusive manner while documenting the trajectory and day-to-day patterns for healthcare providers for care and evidentiary purposes.

The ecosystem consists of hardware and software components. The hardware is comprised of heterogeneous IoT devices, intelligent routers that integrate these devices, and a heterogeneous processing platform. The software components include integration software within the person's home, implementations of learning algorithms to provide self-adaptation, and service-related software to use the cloud as well as exchange sensitive information with health service providers and other care partners. These components can be further categorized into the following roles and responsibilities: (1) IoT devices that sense important information about the person's interaction with their environment; (2) processing platforms that allow for processing of the sensed information and automatic recommendations based on sensor data; and, (3) use of an integrated service for automated analysis and monitoring through which care partners and the ecosystem interact with each other. The system also needs to allow users flexibility as to how their data is used and shared.

The IoT devices include the proposed devices mentioned above, and devices that are currently available in the market. For example, door and motion sensors are key to addressing concerns related to navigating surroundings and getting lost. These sensors provide information that the processing platform uses to execute learning algorithms to determine whether the initial care plan constructed by care partners is helpful to the person, and if not, then adjustments are dynamically proposed. Certain personalization and adjustments of the caregiving plan can be automatically deployed, but some require authorization. This authorization would be enabled via the integrated service system, where the suggested adjustments are communicated to the care partners who approve them before the ecosystem seamlessly alters the deployment software. Note that this would require limited physical intervention from the care partner. Consider a user whose disease progresses over time where initially the user could operate the stove without any assistance but gradually requires reminders and at more advanced stages, needs automated turn-off capabilities. During early stages, the care plan may want the user to be independent and operate the stove themself; hence, the sensor only monitors that the stove is turned off when the user is not near the stove for an extended period of time. However, when the learning algorithms identify several instances where the user has forgotten to turn off the stove, automatic reminders could be sent via the ecosystem. In such situations, care partner intervention may not be required. At later stages, the functionality of the ecosystem will adapt according to a person's progression of the disease and the availability of care resources in the circle of care. The proposed approach addresses the need to provide accurate indicators of disease progression to the care providers and the timely adaptability of a person-centred care plan, particularly in terms of self-care at home.

4.2 IoT device research

This IoT ecosystem requires a heterogeneous mix of portable and wearable IoT devices. By leveraging existing circuit and system technologies wherever possible, focus can be placed on security, ecosystem integration, and energy management aspects that are crucial to IoT device deployment in a field trial. IoT devices applied to self-care are typically powered by a battery that imposes strict constraints on performance and the quality and duration of service. We need to improve the energy efficiency of existing technologies by modifying key circuit functions that harvest energy and extend IoT devices' battery and service life for low data rate (i.e., 1-100kbit/s) ADRD applications outlined herein. The first improvement is a solar antenna (sol-ant) capable of harvesting light (from the solar cell) and microwave energies (from the antenna) simultaneously [23]. The second augmentation is energy harvesting, storage and delivery via a power management sub-system that extends battery and service lifetimes substantially.

A block diagram of the proposed autonomous wireless system is shown in **Figure 2**. It consists of a wireless transceiver, baseband signal processing circuits, embedded memory, a microcontroller, power management, and CMOS sensors. Autonomy for the wireless system reduces maintenance (e.g., battery charging, replacement). The wireless transceiver shares information collected by the CMOS sensors with smartphones, wireless hotspots, and sensor nodes in the ADRD ecosystem. The goal is to build an autonomous wireless system leveraging existing commercial technologies augmented by the solar and power management sub-systems. Energy harvested continuously by the solar can be stored on a supercapacitor or used to recharge a button-cell battery. The transceiver uses the button cell as a start-up power source, extending its operating lifetime to 3–5 years. Poor energy efficiency reduces operational lifetime and increases battery size, which is undesirable in the ADRD application. If a continuous operating of 50 days from a 10-gram Li- ion button-cell battery (i.e., 120 W-h/kg energy density) is desired, a transceiver (Tx/Rx) energy efficiency below 10 nJ/bit is required, i.e., 10x better than conventional technologies such as WiFi, Bluetooth or Zigbee. The aim is to extend the service time of the wireless transceiver operating at 1-100kbit/s, and push efficiency below 10 nJ/bit by harvesting energy from multiple sources using the autonomous power management system. Sources of energy available in a typical home are: light, thermal, mechanical vibration, and radio-frequency (RF) energies.

A photovoltaic solar cell antenna (solant) capable of harvesting light and RF energies are capable of generating more energy from a surface area of just a few cm^2 when operating indoors than other methods [24]. Unfortunately, solar and other renewable energy sources are intermittent. Therefore, energy harvested from the solant must

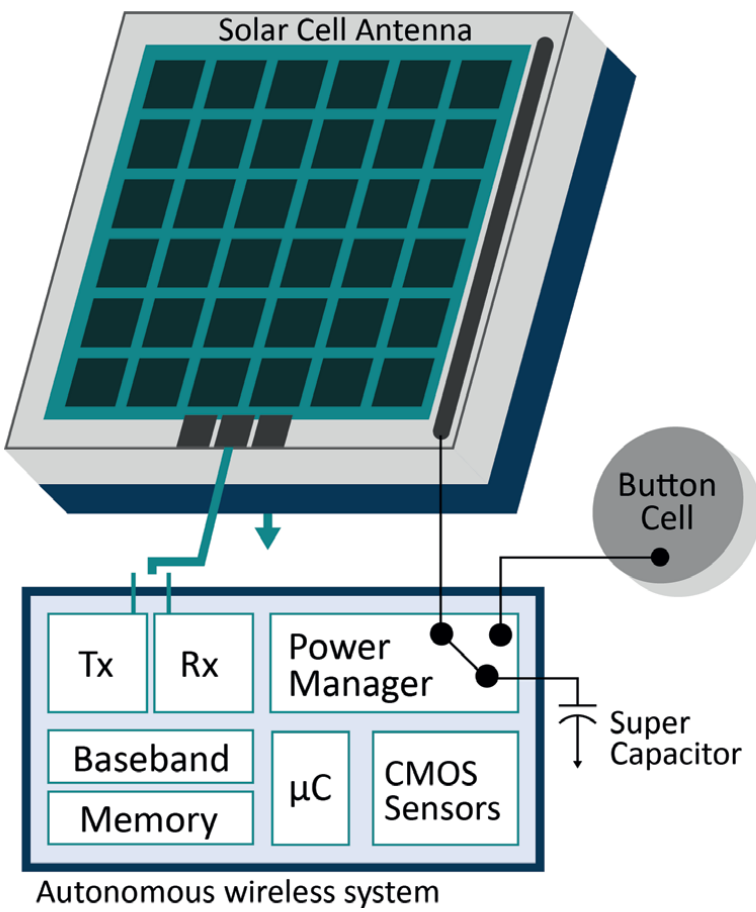

Figure 2.
Block diagram of the proposed autonomous wireless system.

be stored on a high-density supercapacitor and in a rechargeable button battery via a charge pump. The 1-Farad supercapacitor stores enough energy from the solant to bridge peaks in energy demand from the wireless transceiver. Energy from the battery initially bootstraps the power management sub-system system (i.e., 'cold start' when the supercapacitor is discharged). A DC-DC converter draws energy from the supercapacitor to operate the wireless transceiver, sensor interface, and digital circuitry when required. It converts a voltage ranging from 0.6–2.75 V to a regulated 0.9 V supply for the CMOS transceiver. The power consumption of digital and memory circuits has an exponential relationship with the supply voltage. It makes sense to lower the voltage and reduce the power consumption. It is attractive for large memories where the leakage power is high. However, a simple voltage reduction is not without its challenges. The memory access time is increased significantly with reduced voltage. In addition, the memories' ability to retain data is also reduced linearly with the voltage reduction. Data retention is further eroded due to manufacturing variations in advanced technologies. Recent research demonstrated memories and digital circuits working at 250–300 mV range for low-power and low-energy applications [24, 25]. However, additional investigation is needed for ultra low-voltage (less than 200 mV) digital and memory circuits to further enhance power and energy efficiency to extend the battery life.

4.3 Safety, security, privacy and trust considerations

Security and privacy are arguably the most important attributes that must be provided at the level of the ecosystem rather than for components only. Of course, the ecosystem is a composition of those components; thus, the security and privacy of and from components are necessary but not sufficient for the system as a whole. Systems security and privacy are well known to be significant technical challenges in any system of reasonable scale and complexity. Challenges can be categorized as (1) Security of individual components and privacy protection of data within individual devices, (2) Security of the human users from the system, (3) Security of the system, i.e., the composition of the individual components, (4) the privacy the system provides to the data both at rest and in transit and (5) the ability for users to make informed choices regarding privacy and system use. Towards (1), considerable work has already been done on both tamper-resistance of devices and the security and privacy such devices provide [26, 27]. The technique in this regard is to carefully isolate data and components that need to be trusted from those that do not and enclose the former using, for example, tamper-resistant screws to preclude physical access, and also hardware-enforced isolation built into the. Cutting-edge techniques such as lightweight cryptography can ease computation and communication overhead and yet provide adequate security guarantees [28].

Towards (2), a necessary design constraint is obtaining consent. The design and engineering of the system, particularly its usability aspects, must (a) clearly solicit user-consent, and, (b) do so in a simple, intuitive manner from the standpoint of Human Computer Interaction [29–31]. Towards (3), it is well-established in the field that the composition of two secure systems is not necessarily secure. Consequently, sound techniques for secure composition are required. Towards (4), compliance with privacy legislation, specifically the Personal Information Protection and Electronic Documents Act (PIPEDA), as well as with the corresponding US Health Insurance Portability and Accountability Act (HIPAA), will be critical. Properties such legislation requires will be encoded precisely in a manner that can then argue strongly, or even prove, that they have been met. Regarding (5), developing and implementing an at-home monitoring system has a multitude of complex ethical challenges regarding understanding what the system does and being able to make informed choices on what and when information is used. This open problem has remained a significant barrier to the uptake and use of these types of systems. Participatory action research with PwADRD and their care partners can be used to create new ways of supporting informed consent. This can be supplemented by the progressive information and permissions paradigm that is currently used and familiar to people living with dementia as an underlying framework [32–34].

The shift from deploying sets of devices to a secure learning ecosystem represents a major advent in technology and system thinking. Attention to minimizing energy needs and making the system cost-effective are essential in making the system sustainable and affordable on a large scale. The ability to help individuals stay longer in their own homes and delay the shift to a care facility as long as possible will benefit their quality of life and make the best use of scarce economic resources. Currently, waiting lists for long-term care are long, and the dangers of the rapid spread of infection in these facilities are apparent. Although the application here is to ADRD, the ecosystem could also be applied to other areas of healthcare where monitoring of persons could be beneficial.

4.4 General purpose technology in the assistive technology ecosystem

Our society has generally become more inclusive. As a result, many technologies designed for the general population have embedded functions to be used as assistive technology. The Association for Advancement of Assistive Technology in Europe (AAATE) has identified the convergence of general purpose (i.e. mainstream) technology and assistive technology as an ongoing trend where products will offer more comprehensive ranges of functions that can benefit a larger portion of the population [35]. An example of this trend is the replacement of disability-specific electronic aids to daily living with mainstream smart home technologies such as Google Home and Amazon Echo. As technology design continues to focus on adaptability and flexibility, mainstream technologies will provide more affordable and better options for people with disabilities to access features that would traditionally only be available in assistive technologies. Using mainstream technologies in the IoT ecosystem presented in this chapter also has the potential to save costs and reduce resource demands of the healthcare system, thus significantly improving the ecosystem's sustainability. This has been demonstrated in a study conducted by the Centre for International Research on Care, Labour and Equalities in England [35]. Other studies highlighted the potential of mainstream technology to support people's care without damaging their sense of self [36]. It is reported that the participant prefers mainstream technologies as they are perceived as commonplace and a part of everyday life. This study also identified the need to understand their contribution to social isolation and cautioned against underestimating the demand for Wraparound services [36].

5. Systematic changes

Inevitably, the cost is a barrier to AT adoption. In Canada, healthcare is mainly the province's responsibility, and variations in funding mechanisms, eligibility criteria, types of funded devices, and extend of funding exist across provinces [37]. Within each province, based on the type of recipient and the program for which they are seeking support, funding may come from federal and provincial programs, private insurance, charity programs, foundational grants, and donations. The lack of a holistic approach between funding sources makes it difficult for a PwADRD to navigate the funding system, resulting in service gaps where groups need AT without financial support. Restrictive eligibility criteria can further limit access by increasing an individual's burden to demonstrate financial and AT needs. Specific functional disabilities may limit entitlement, leaving more generalized AT or AT not related to the specific disability inaccessible, even if they have the potential to improve the user's overall quality of life.

These challenges are compounded by variations in eligible device types and considerations for customization, maintenance, repair, and replacement. Certain programs require the technology to have been on the market for a minimum of 1 year before it is approved for funding [37]. Other programs may look at the context of how the AT is to be deployed and will only supply AT as part of a package to meet a specific need. Funding for general-use technologies is also inconsistent between programs, with some promoting the use of consumer products while others exclude these from consideration. To further complicate the issue, some programs will support custom build and upgraded solutions, while others only fund basic models, with applicants having to pay out of pocket for any upgrades. Lastly, programs may only fund AT that supports essential daily living activities and limit their access to leisure purposes. There is also little consideration for user training for fully utilizing the AT they have received. Some programs will provide education and training support, but many consider the device as a one-time expense with minimum funding for Wrap around services. The treatment of AT access as isolated events can also create challenges as an individual's situation changes, triggering a need for reassessment of their AT needs. Without a funding mechanism to support ongoing evaluation, the impact of funding programs may be limited.

A holistic approach will be essential for various programs to continue their important work of providing meaningful AT access. However, gaining access to AT is only one of many steps towards PwADRD's self-care and improved quality of life. With the fast advent of technology, individuals and society continue to evolve rapidly. Systematic changes are needed, not only in funding but also in infrastructure and human resource building, to support the adoption of the IoT ecosystem outlined in this chapter. Along with AT, these system changes will empower and engage PwADRD and their caregivers in its design, funding, use, and evaluation and, ultimately, enable PwADRD to lead meaningful lives.

6. Conclusions

In this chapter, we presented an assistive technology ecosystem that enables independence and promotes interdependence for PwADRD and their living environment. More than technology alone will be needed to solve the challenges PwADRD, their caregivers and our society face. Systematic changes, including user-centeredness in technology solutions, employment of participatory action methodologies for technology design and implementation, funding and care models are needed to create an affordable and sustainable ecosystem as outlined in this chapter.

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Conflict of interest

The authors declare no conflict of interest.

Appendices and nomenclature

ADRD	Alzheimer's disease and related dementia
PwADRD	A person living with Alzheimer's disease and related dementia
AAL	Active Assisted Living
AT	Assistive Technology
IoT	Internet of Things

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References

[1] World Health Organization. Dementia [Internet]. 2022. Available from: https://www.who.int/news-room/fact-sheets/detail/dementia. [Accessed: December 21, 2022]

[2] Alzheimer Society of Canada. Dementia numbers in Canada [Internet]. 2022. Available from: https://alzheimer.ca/en/about-dementia/what-dementia/dementia-numbers-canada#ref1. [Accessed: December 21, 2022]

[3] Alzheimer's Association. Alzheimer's disease facts and figures. Alzheimer's & Dementia. 2019;**15**:321-496

[4] Alzheimer's Society of Canada. Prevalence and Monetary Costs of Dementia in Canada. Alzheimer Society of Canada; 2016

[5] Columbus L. A roundup of 2018 enterprise Internet of things forecasts and market estimates. Comfort Life. Memory Care Costs. 2018. Available from: https://www.comfortlife.ca/retirement-community-resources/retirement-costs-ontario#memory-care

[6] Public Health Agency of Canada. What we Heard Report: Informing a Dementia Strategy for Canada. Ottawa, Canada: Public Health Agency of Canada; 2019

[7] Dupuis SL, Epp T, Smale BJA. Caregivers of Persons with Dementia: Roles, Experiences, Supports, and Coping. Literature Review Prepared for the Ministry of Health and Long-Term Care and Ontario's Senior's Secretariat as Part of Ontario's Alzheimer Strategy (Imitative #6 – Research on Caregiver Needs). Waterloo, ON: Murray Alzheimer Research and Education Program; 2004. p. 111

[8] Fadrique FL, Rahman D, Morita PP. The active assisted living landscape in Canada. CSA Group. 2019. Available from: https://www.csagroup.org/article/the-active-assisted-living-landscape-in-canada/; https://preprints.jmir.org/preprint/15923

[9] Baum F, MacDougall C, Smith D. Participatory action research. Journal of Epidemiology and Community Health. 2006;**60**(10):854-857. DOI: 10.1136/jech.2004.028662

[10] Dupuis S, McAiney C, Loiselle L, Hounam B, Mann J, Wiersma EC. Use of participatory action research approach to develop a self-management resource for persons living with dementia. Dementia (London). 2021;**20**(7):2393-2411. DOI: 10.1177/1471301221997281

[11] Tiersen F, Batey P, Harrison MJC, Naar L, Serban AI, Daniels SJC, et al. Smart home sensing and monitoring in households with dementia: User-centered design approach. JMIR Aging. 2021;**4**(3):e27047

[12] Goeman DP, Corlis M, Swaffer K, Jenner V, Thompson JF, Renehan E, et al. Partnering with people with dementia and their care partners, aged care service experts, policymakers, and academics: A co-design process. Australasian Journal on Ageing. 2019;**38**(52):53-58. DOI: 10.1111/ajag.12635

[13] Mayer JM, Zach J. Lessons learned from participatory design with and for people with dementia. In: Proceedings of the 15th International Conference on Human-Computer Interaction with Mobile Devices and Services. New York: ACM Digital Library; 2013. pp. 540-545. DOI: 10.1145/2493190.2494436

[14] Bricout J, Greer J, Fields N, Xu L, Tamplain P, Doelling K, et al. The "humane in the loop": Inclusive research design and policy approaches to foster capacity building assistive technologies in the COVID-19 era. Assistive Technology. 2021;**34**(6):644-652. DOI: 10.1080/10400435.2021.1930282

[15] Herring J. Health as vulnerability; interdependence and relationality. The New Bioethics. 2016;**22**(1):18-32. DOI: 10.1080/20502877.2016.1151255

[16] Liu L, Daum C, Miguel Cruz A, Neubauer N, Perez H, Ríos RA. Ageing, technology, and health: Advancing the concepts of autonomy and independence. Healthcare Management Forum. 2022;**35**(5):296-300. DOI: 10.1177/08404704221110734

[17] Bennett CL, Brady E, Branham SM. Interdependence as a frame for assistive technology research and design. In: Proceedings of the 20th International ACM SIGACCESS Conference on Computers and Accessibility, ACM. New York, NY, USA: ASSETS '18; 2018. pp. 161-173. DOI: 10.1145/3234695.3236348

[18] Hoel V, Ambugo EA, Wolf-Ostermann K. Sustaining our relationship: Dyadic interactions supported by Technology for People with dementia and their informal caregivers. International Journal of Environmental Research and Public Health. 2022;**19**(17):10956. DOI: 10.3390/ijerph191710956

[19] Liu L, Daum C, Neubauer N, Cruz AM, Rincón AR. What is Autonomy and Independence in the Context of Aging in an Era of Technology?. In: Autonomy and Independence. Synthesis Lectures on Technology and Health. Cham: Springer; 2022. DOI: 10.1007/978-3-031-03764-1_1

[20] Lindemann K. The ethics of receiving. Theoretical Medicine and Bioethics. 2003;**24**:501-509

[21] Sobel K, Rector K, Evans S, Kientz JA. Incloodle: Evaluating an interactive application for young children with mixed abilities. In: Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16). New York, NY, USA: Association for Computing Machinery; 2016. pp. 165-176. DOI: 10.1145/2858036.2858114

[22] By Us For Us. Tips and Strategies. 2018. Available from: https://the-ria.ca/wp-content/uploads/2018/11/BUFU-Guide-Tips-and-Strategies_AODA.pdf

[23] Danesh M, Long JR. An autonomous wireless sensor node incorporating a solar cell antenna for energy harvesting. IEEE Transactions on Microwave Theory and Techniques. 2011;**59**(12):3546-3555

[24] Saputra N, Long JR. A fully integrated wideband FM transceiver for low data rate autonomous systems. IEEE Journal of Solid-State Circuits. 2015;**50**(5):1165-1175

[25] Nabavi M, Sachdev M. A 290-mV, 3.34-MHz, 6T SRAM with pMOS access transistors and boosted wordline in 65-nm CMOS technology. IEEE Journal of Solid-State Circuits. 2017;**53**(2):656-667

[26] Patel D, Sachdev M. 0.23-V sample-boost-latch-based offset tolerant sense amplifier. IEEE Solid-State Circuits Letters. 2018;**1**(1):6-9

[27] Halperin D, Heydt-Benjamin TS, Fu K, Kohno T, Maisel WH. Security and privacy for implantable medical devices. IEEE Pervasive Computing. 2008;**7**(1):30-39. DOI: 10.1109/MPRV.2008.16

[28] AlTawy R, Rohit R, He M, Mandal K, Yang G, Gong G. sLiSCP: Simeck-Based

Permutations for Lightweight Sponge Cryptographic Primitives. In: Adams C, Camenisch J, editors. Selected Areas in Cryptography – SAC 2017. Lecture Notes in Computer Science. Vol 10719. Cham: Springer; 2017. DOI: 10.1007/978-3-319-72565-9_7

[29] Dwork C, McSherry F, Nissim K, Smith A. Calibrating Noise to Sensitivity in Private Data Analysis. In: Halevi S, Rabin T, editors. Theory of Cryptography. Lecture Notes in Computer Science. Vol 3876. Berlin, Heidelberg: Springer; 2006. DOI: 10.1007/11681878_14

[30] Dewing J. From ritual to relationship: A person-centred approach to consent in qualitative research with older people who have a dementia. Dementia. 2002;**1**(2):157-171

[31] Dewing J. Participatory research: A method for process consent with persons who have dementia. Dementia. 2007;**6**(1):11-25

[32] Boger J, Mulvenna M, Moorhead A, Krul J, Bond R, Jutai J. Ethical issues in technology for dementia. In: Astell A, Smith S, Joddrell P, editors. Using Technology in Dementia Care: A Guide to Technology Solutions for Everyday Living. London and Philadelphia: Jessica Kingsley Publishers; 2019

[33] Boger J, Jackson P, Mulvenna M, Sixsmith J, Sixsmith A, Mihailidis A, et al. Principles for fostering the transdisciplinary development of assistive technologies. Disability and Rehabilitation: Assistive Technology. 2017;**12**(5):480-490. DOI: 10.3109/17483107.2016.1151953

[34] Hussein T, Boger J, Rudzicz F. The impact of design on feelings of trust of online information for family caregivers of people with dementia. In: Proceedings of the 32nd International BCS Human Computer Interaction Conference. Belfast United Kingdom, July 2018. Vol. 32. 2018. pp. 1-6

[35] Layton N, Steel E. The convergence and mainstreaming of integrated home Technologies for People with disability. Societies. 2019;**9**(4):69-80. DOI: 10.3390/soc9040069

[36] Hamblin K. Sustainable social care: The potential of mainstream “smart” technologies. Sustainability. 2022;**14**(5):2754. DOI: 10.3390/su14052754

[37] Marchand D, Nakhuda H, Dolcine B, Li Y, MacDougall D. Funding and access to assistive technologies: Electronic aids to daily living. Canadian Journal of Health Technologies. 2021;**1**(5). DOI: 10.51731/cjht.2021.68

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This book covers a wide range of subject areas, including assisted living, social robots, augmentative and alternative communication, connectivity, artificial intelligence, and robot design. Each chapter is authored by experts in their respective fields and offers readers theoretical and applied scientific papers that can serve as original research or review papers. This valuable volume is essential for researchers, practitioners, and anyone interested in developments in assistive technology. It explores trends and innovations in the field, demonstrating how assistive technology is enhancing the lives of people with disabilities or reduced mobility, and the elderly. The book is a comprehensive overview of the latest research and advancements in assistive technology, making it an essential addition to any library for both seasoned researchers and those just starting to explore the field. We are grateful to the authors for their invaluable contributions to this book, which would not have been possible without their generosity in sharing their knowledge and experiences.

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