Chapter

Perspective Chapter: Digital Assistive Technologies

Vivian Vimarlund and Diana Zandi

Abstract

The use of digital technologies has been described as a facilitator integrating services and offering facilities to support individuals with impairments. In this chapter we identify level of advancement, trends, and challenges in the growing area of digital assistive technologies. Interview with experts and a literature search were performed. The outcomes of this study shown that the generic use and adoption of technologies involves complexity and changes in several aspects and, specifically, requires changes in the overall practice environment. However, the real challenge is not to identify technologies or to prioritize products, policies, or praxis, rather it is to build infrastructures, to match levels of maturity with products or services, and to reduce the technical, and socio-economic inefficiencies that constrain the further development of the area.

Keywords: digital assistive technologies (DAT), challenges, levels of advancement, infrastructure, socio-technical and socioeconomic issues

1. Introduction

About 15% of the world's population lives with some form of disability. One billion people need assistive technology to live healthy, productive, and independent lives, and to participate in education, the labor force, and civic life [1–4]. It is estimated that this number will double by 2050 [4, 5]. With a progressively aging population and the rapid spread of chronic diseases (e.g., osteoarthritis, diabetes, depression, obstructive pulmonary diseases, dementia etc.), as well as continuing improvements in the methodologies used to measure disability, the number of people living with some form of impairment will rapidly increase, in virtually all countries. To overcome differences based on social and structural factors in the delivery of services to individuals with impairments (the elderly and individuals with disabilities), there has been a significant acceleration over the past 50 years in the development and use of digital assistive technologies (DAT) that improve the well-being of individuals in need [4, 6]. Technologies such as intelligent systems, assistive robots, wearable sensors, have gained attention due to their capacity to create real-time services [7, 8]. In parallel, concepts such as smart homes, intelligent homes, assistive technology, welfare technology, and ambient assisted living have flourished and are used to index research and development contributions aimed at supporting activities or services that address the requirements of individuals with impairments. Further, the use of

digital assistive technologies has been described as an enabler integrating services and facilities that support and connect individuals [8–15]. During the last two years, a series of action plans have been developed to accelerate the development of online services. Private and public organizations have been forced to become more system-oriented to increase the capacity of clients, service providers, and stakeholders to respond to challenges such as the COVID 19 pandemic [16].

2. Aim

In this chapter we identify level of advancement, trends, and challenges in the growing area of digital assistive technologies. The outputs of the study can contribute to identify progression and pre-requisites to achieve a sustainable evolution of the area.

3. Method

Data has been sampled in several steps and taken from different sources with the aim to achieve consistency in the outcomes. At the first step, we performed interviews with six experts representing: (i) the WHO, (ii) academic institutions or research centers, and (iii) interest groups belonging to international scientific associations with market connections, as well as representatives of interest organizations with the aim of discussing barriers, facilitators, and issues of relevance for the implementation and adoption of digital assistive technologies. The interviews lasted between 60 and 90 minutes, and all of them were performed between January and March 2021. The interviews followed a semi-structured format, with guiding questions being used to ensure that a consistent dataset was collected from each respondent. Detailed notes were taken during the interviews. A summary of the main issues discussed during the interview was given by the interviewer at the end of the interview with the aim of ascertaining that the interviewee had been correctly interpreted. The answers were then registered in tabular form to facilitate comparison between interviews. In the next step we performed a literature search to capture examples and to illustrate progression or innovation of emerging technologies in the area. The literature search was performed in an iterative manner. In contrast to a systematic review, the interactive process allowed us to summarize the findings of the literature and rapidly achieve a broad coverage of the field. The concepts of ambient assisted living, smart homes and assistive technologies were used to search examples of implemented or suggested technologies. The search for literature was entirely conducted using electronic databases such as: Science IEEE Xplore Digital Library (https://ieeexplore.ieee.org/Xplore/home.jsp); ACM Digital Library (https://dl.acm.org/); and Direct (https://www.sciencedirect.com/).Only peer-reviewed publications written in English that discussed issues related to one or more of: systems, devices, products, services, to support individuals with impairments were included. Articles aiming to resolve purely clinical situations were not included. We adapted a model developed in a previous study to capture maturity and levels of advancement of eHealth applications to group DAT examples [15]. The examples were then associated with some of the area they aimed to support (accessibility, connectedness, engagement, and/or efficiency) and to the functions to which they contribute: cognition and sensory functions, mobility, daily living, communication, education, recreation, and/or sport.

4. Results

The ways in which DAT can support individuals with impairments in the long run, and the expectations and challenges for the further and sustainable development and distribution of DAT, as expressed by experts, researchers, and representatives from interest organizations, are described in **Table 1**.

	Expectations	**Challenges**
WHO experts	Ability to monitor, follow up and support individuals with **i**mpairments at a distance	• Absence of individual-based information to further the development of services • Different rules, policies, laws, and praxis in different countries
	Give individuals the opportunity to be included in societal activities. For instance: education, the workforce, health and social care, and leisure time activities	• Different levels of ICT maturity in different regions and countries • Absence of infrastructure (social or technical)
	Access to DAT and to real-time information offered by the community	• Lack of connectivity • Absence of technical structures and virtual platforms • Social and political structures are different in different regions
	Market products (devices and applications) are becoming cheaper because of global competition.	• **T**echnical, or assistive products do not face the same level of competition as other products, and the number of items sold is very small, which might not allow an economy of scale effect. • DAT products or services are still expensive for some groups of consumers (i.e., low-income versus high-income countries). • Willingness to pay and budget constrains can be influenced by individuals' age, gender, income, education, and/or where they live.
Researchers	Opportunity to offer digital services (i.e., eHealth services, or online educational services)**.**	• Difficult to keep service providers up to date with technological advancements
	Opportunity to support individuals with impairments at distance while maintaining service quality	• Mismatch between state-of-the-art of the technology and organizational or individual capacity to buy, distribute, or use devices, products, or services**.**
	Preventing emergency situations and reducing the burden of health and social care	• Complex organizational barriers or absence of clear ownership of the issues related to assistive technology
	Allow individuals to live more independently and for longer at home	• Different levels of ICT maturity at both the provider and the customer level
	Personalization of services	• Individual-based data is not accessible

	Expectations	Challenges
	Possibility to offer assistive technologies and services worldwide	• Differences in the level of technological advancement in different regions • Major focus on technology rather than on issues related to the acceptance of DAT • Absence of networks to develop collaborative road maps
Representatives from interest organizations	Access to mainstream devices and services for individuals with impairments	• Difficult to scale products • Focus on innovative products rather than on how to stimulate a circular economy, or outlet of DAT • The user of the technology is frequently someone else (e.g., informal caregivers) not the single individual (end-user).
	Opportunity to develop a digital society and become connected	• Market dominance (few actors) • Absence of basic infrastructures in some regions (e.g., absence of electricity) • Absence of educational programs to train users and personnel

Table 1.
Expectations and challenges for further development of DAT: Opinions from experts, researchers, healthcare, and market representatives.

It is interesting to note that the mismatch between the rapid development of technology and the capacity to buy, use, and distribute products are mentioned by researchers as among the major issues for the sustainable distribution of DAT. It is also interesting to note that technology itself (type of devices, services, or technical solutions) is considered to play only a partial role in the integration of individuals into virtual worlds. Social barriers, and the absence of technical structures, or even basic structures, as well as the absence of clear ownership of DAT, and the absence of training programs for both users and suppliers, are mentioned by the respondents as major issues that need to be resolved before continuing to discuss the further development of DAT. An interesting observation is that none of the interviewees identified areas or types of services that could be developed globally, nor did they mention the customer and their preferences, or the importance of age, gender, culture, or willingness to change routines as major constraints for the acceptance of DAT. Some of the interviewees mentioned the importance of the market and the market dominance of some companies for the sustainable development and distribution of DAT.

In the next step we group examples of digital assistive technologies and illustrate trends, levels of technological advancement, and challenges. (See **Figure 1**).

Group 1: Diversity in the development of the infrastructure and distribution of digital assistive technology: Analog solutions and isolated technologies.

The contexts (regions or local communities) in which digital assistive technologies are implemented do not always have digital infrastructures in place that support the implementation and distribution of DAT, and no clear organization for

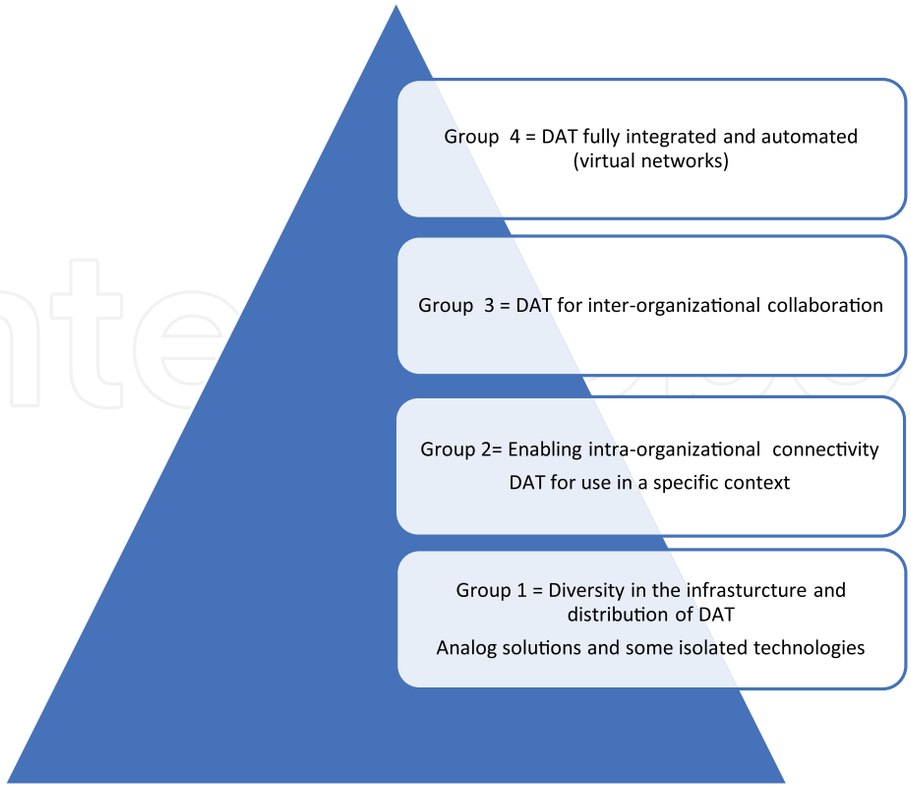

Figure 1.
Digital technology advancement, and pre-requisites. From diversity in the infrastructure to virtual networks (adapted from Vimarlund V., Kock S. 2016) [15].

the supply or distribution of services is in place. The accessibility of DAT cannot be guaranteed, and the use of products and services depends on socio-economic, technical, and cultural variables as well as geographical differences [14, 15, 17–27]. In the same context, it may be possible for some individuals to acquire or rent DAT devices or services, while others cannot. Issues related to the distribution of assistive technologies, in general, belong to different political actors and are not coordinated with the health or social care system. Basic phones with low functionality that primarily allow voice calls, SMS, are used as an alternative, in the absence of technical platforms, to access some services. Examples of products, devices, and technologies for this group are listed in **Table 2**.

Paradoxically, the main challenges at this level are not related to technology or technological advancements. The real challenges are: a) how to build platforms that provide solid and efficiently support to deliver products and services, b) how to build a roadmap that sustains the digital transformation needed to support the accessibility, and distribution of services, c) how to use simple available technologies, e.g. mobile phones to deliver basic DAT services, and d) how to develop an equitable and equal model that ensures security and performance and at the same time considers issues related to lifestyles, cultural differences, language differences, and d) how to motivate individuals to test and use DAT.

Group 2: Enabling intra-organizational connectivity for service transfer.

As countries advance in the development of their technical infrastructures, they make the Internet accessible to their citizens. DAT are mainly used to support the provision and delivery of services that facilitate one-way communication between one individual and one service provider. DAT are designed to address specific situations (e.g., to recognize actions or situations within the environment

Areas	Functions	Examples of products, devices, and services
Efficiency	Cognition and sensory functions	Conventional products to assist cognitive functions for planning and/or scheduling of services: • Memory devices and pill box reminders, alarms, etc. • Medication dispensing and management, rimers (time a person expends in the bath) • Sensory functions, e.g., spectacles, software for screen magnification and reading, hearing aids
Connectedness	Mobility	• Wheelchairs equipped with Bluetooth modules • Spinal orthotics and cervical collars equipped with dials to select the correct height setting
Accessibility	Daily living	• Adjustable Toilet chairs, diapers • Products for housing, work, and living environment or products for improvement and home modifications e.g., handrails, grab-bars, controlled lighting. • Basic phones for visually impaired individuals to make phone calls, access apps, read and send text messages and emails, set calendar reminders
Accessibility	Communication and education	• Voice and speech training devices • Braille apparatus and screen readers • Braille translator (software to translates electronic documents into Braille) • Audio format (to access and read information through hearing) • Screen-reading software (to allow people with low vision and the blind to convert text on a computer screen and in documents to synthetic speech)
Engagement	Recreation and sports	• Modified sports equipment to facilitate engagement in different leisure-time activities.

Table 2.
Examples of areas, functions, and products in group 1.

through monitoring or follow-up, or to detect and respond to potential emergencies), and to enable individuals to remain active, socially connected, and independent [15, 26–33] (see **Table 3**).

DAT applications for intra-organizational connectivity normally do not allow opportunities to interact or exchange information in real-time, but they do allow users to capture and accumulate real-time data. They have neither automation nor verification mechanisms. The main outcomes are related to reducing work overload and improving individual follow-up and monitoring. Information is transferred in a digital format, and individual recipients of services do not necessarily need to have a high level of ICT maturity and digital literacy. Investments in DAT are mainly made to reduce costly and time-consuming activities (e.g., ordering goods or medicines, searching for information), or to facilitate the management, monitoring, and follow-up of individuals. At the organizational level, DAT tend to reduce the number of unintentional errors, allows rapid and effective access to information (for the planning and distribution of resources), and enables the reallocation of time and resources (personal, administration for follow-up), organizational learning, and shorter lead times for decision-making. The socio-economic consequences of the implementation

Areas	Functions	Examples of products and services
Efficiency	Cognition and sensory functions	• Alarms to detect emergencies (e.g., falls at home) • Wearable sensors to detect movement (daily monitoring) or to monitor vital signs • Devices and sensors to support, follow up, and monitor individuals with cognitive impairments • Mobile or wearable devices for automatic translation between any languages in cases where pronunciation is unclear.
Connectedness	Mobility	• Devices or products to facilitate mobility and transport (e.g., wheelchairs connected to the internet) • Wheeled robots and/or devices that facilitate mobility • Voice recognition applications to search information and to facilitate accessibility to certain services such as transport GPS and telecommunication devices • Digital maps for pedestrians delivered to hand-held devices and smartphones
Accessibility	Daily living	• Consumer-oriented services, e.g., e-commerce alternatives to order foods and/or goods, medicines, or assistive technology products. • Digital assistants and navigation tools that provide assistance with audio support. . • Monitoring and reminding via electronic drug dispenser systems (electronic, pill or medicine dispenser systems with built in reminder)
Engagement	Communication, education, and recreation	• Screen readers to facilitate searching for and sharing information • Music apps, reality games to manage pain or for individuals with cerebral paralysis • e-books that can be uploaded and used at the individual level to facilitate the acquisition of knowledge Graphical user interfaces, text editing software and telephony services

Table 3.
Examples of areas, functions, and products in group 2.

and use of DAT at this level are normally short-term results due to reductions in transaction costs[1] when administrative services can be rationalized.

Group 3: Inter-organizational collaboration.

In this group, DAT are used to allow two-sided communication, transfer information within and between different organizations, and to support across communication in real-time. DAT allow access to online services and interactivity of different networks. Legislation concerning personal data privacy (including data access, exchange, and

[1] The total costs of making a transaction, including the cost of planning, deciding, changing plans, resolving disputes, and after-sales. Transaction costs are one of the most significant factors in business operation and management.

Areas	Functions	Examples
Connectedness	Communication	• Text and voice messaging with pictures and speech • Mobile voice user interface and smartboards • Ontologies and user models for activity recognition and real-time monitoring
Engagement	Education and training	• Interactive learning systems that support individuals with disabilities to actively participate in educational programs • Autonomous learning-based example or semantic information • Virtual reality games to learn, train, and improve cognition
Accessibility	Daily living	• Voice assistance and virtual platforms • Video-based home monitoring and internet-based services (that connect individuals with different service providers) Digital services that allow access and interaction between providers and consumers of services (e.g., net doctors, legal services) Digital media to offer leisure-time activities at a distance Smart phones wirelessly connected to body sensors (to monitor health and clinical signs remotely (e.g., EKG, tests etc.)

Table 4.
Examples of areas, functions, and products in group 3.

ownership) as well as rules for data processing as well as certification principles are in place to make electronic transactions legitimate and to build trust among stakeholders.

Improvements in digital infrastructure, such as bandwidth or communication speed, information storage databases, web services and backups, standard formats for data transmission, data encryption, password protection in support of digitalizing information and data exchange are in place based on nationally adapted recommendations based on international guidelines [34]. DAT belonging to this group are characterized by a multiple organizational perspective and presupposes investments in assistive technologies that support cooperation, communication, and workflow as well as the production of services between several different suppliers and providers i.e., (health and social care organizations, business enterprises, non-profit organizations [35–41]. Consumers and users can access multi-home services (similar services produced and delivered by different producers) through platforms that allow interaction between suppliers and consumers. An issue related to DAT, however, is the asymmetry in the information that exists about the number of accredited companies, hybrid companies (companies that provide welfare services[2], communication, and even other services), service companies, or publicly owned companies, stakeholders, and entrepreneurs active in the market. Most of the applications and services are aimed at enhancing communication and socialization within a community. Smartphones are used as the most common virtual platform to access the services and information available on the Internet (see **Table 4**).

Many of the examples belonging to this group refer to devices that help their users to receive or capture information from the environment to actively participate in their

[2] Services that cover the basic well-being of individuals and society. They may be provided as a citizenship right and managed by governments and institutions or private actors. Welfare services usually strive to improve the situation of people in need.

Areas	Functions	Examples of DAT for automation of services
Efficiency	Environment	• Alerts for home • Energy management systems • Robotics, react to touch autonomous or mobile control of temperature etc. • Emergency response systems to monitor risks outside the home environment
Efficiency	Safety and security	• Home safety/security systems • Use of digital identity • Facial recognition to reduce the number of surfaces people need to touch • Fraud protection applications
Connectedness	Daily living	• Robots to assist individuals at home or in the workplace • 3D sound to facilitate real-time understanding of the type and position of objects • Transmission of parameters through wireless biomarkers • Companion robots for emotional and social support • Distributed systems with direct data links to laboratories for pattern analyses • Multimodal systems to generate data about vital signs from mobile apps
Accessibility	Communication and transport	• Portals for monitoring and access to online services • Machine learning and pattern recognition for communication and transport • Signaling products and voice interpretation services • Smart sidewalks
Engagement	Education and training	• Learning management systems • Virtual reality for training • Braille keyboard interfaces to guide blind people • Voice transcription apps
Engagement	Leisure time	• Virtual reality games to assist individuals with e.g., cognitive impairments • Interactive products for recreation, sport, culture, and leisure

Table 5.
Examples of areas, functions, and products in group 4.

local community. Digital assistive technology not only detects and reports incidents, but also prevent undesirable events problems with connecting assistive devices and products into everyday living contexts. Remote services are adopted to improve quality of life, support independence, and reallocate resources. New structures created using DAT enable the creation of integrated services to support daily life, avoid social isolation, and/or support social integration. Paradoxically, the main challenges are not related to the implementation of technological innovations or to their functional capacities, but to the willingness of users to engage, to the frequency of their use of services, devices or products, and governance of the same. Smartphones with

adequate mobile coverage and connection to a mobile data network become a critical tool to enable people with impairments to live independent and socially connected lives when the technical infrastructure is not optimal. An important challenge for this group is that the relationship between cost and effectiveness is not necessarily either direct or linear [15].

Group 4: Virtual networks.

Digital technologies belonging to this group require the integration of systems through an infrastructure that sustains vertical integration. This group is characterized by an individually focused perspective and includes investments in DAT innovations in which the receiver (the individual) is an active participant and influences the demand and supply of services at all levels.

Automation of services has reached a mature level, where users are proactively involved in the services they use. At this level, services are transformed from a push to a pull format (they are demand-driven). The virtual context offers accessibility to services delivered by private business partnerships. Data repositories, interconnection, and interoperability, in addition to a reliable networking infrastructure, are in place. Different suppliers and various channels for the delivery of services ensure agile accessibility to services, systems, and devices. Smartphones, the most advanced category of mobile phones, contain many of the functionalities of a computer and allow users to download and operate applications to create customized functionalities and thus interact with, access, and use assistive products [41–48]. Examples of DAT are listed in **Table 5**.

DAT in this group presuppose the development of a 'virtual context', or 'virtual communities', access to the Internet, and connectivity. The paradox of this level is that the benefits derived from the implementation and use of DAT become easier to appreciate, although the technology is interwoven into all activities. DAT products and services belonging to this group are not intended to be standalone solutions. Home or living environments are equipped with information and computing technology and devices that are usually described as the Internet of Things. Consumers (users and workers) have a good level of ICT literacy and can handle, update, and manage their technology.

5. Conclusions

The area of DAT is expected to nurture the digital transformation worldwide, and in parallel to transform the entire value chain, addressing the emergence of infrastructures, new transaction mechanisms for improved trust and security, and the development of strategies to facilitate the distribution and accessibility of DAT. This, however, requires overcoming the challenge to integrate individual systems into networks of actors that bring together civil society, consumers, and producers who are willing to accept the social impacts of the new context [16, 48]. The rapid development of technology and the absence of technical structures, are, however, mentioned by the respondents as major issues that need to be resolved before continuing to discuss the further development of DAT.

This study shown that publications focused on the impacts of DAT emphasize on specific technologies and address generic problems. Furthermore, they are, in general, optimistic and assume that all individuals with impairments will be able to participate in society easily and actively if they use digital technologies. Most of the studies focus on a single functional disability or physical or mental limitation

and discuss early proofs of concept or engage in a theoretical discussion about the effectiveness or contribution of DAT to resolve major socio-technical issues whereas the mainstream adoption of new technologies is not discussed [49, 50]. Most of the publications are related to diseases, geriatrics, healthcare, patient monitoring, artificial intelligence applications, epidemics, telerehabilitation, drug reposition, transport, or to the need to develop policies to ensure the accessibility to DAT. This makes the literature dispersed and fragmented rather than focused and with possibilities to replicate the outputs.

The classification of DAT we have suggested in this chapter, contributes to identifying pre-requisites that need to be fulfilled to achieve a sustainable progress from one step to another. The classification suggested shows further that when identifying the possibilities offered by DAT, it is important to consider issues such as existing infrastructures, maturing level, preferences as well as socio-technical and economic issues. This study demonstrates also, that when opening the 'black box' of DAT, there are several elements and challenges that the global community needs to resolve. Many questions remain to be answered. For instance, it is not yet known whether the COVID 19 pandemic will change patterns of interaction and communication in the long term. As we continue to adapt to the "new" normal of increased digitalization, the time has come for digital technology providers to continue to work closely with the four pillars of society to develop long-term solutions to bridge the digital gap. In future studies it will be necessary to discuss how patters of interactions and communications will change and what is needed to move from one phase to another in parallel to technological innovations which require a flexible strategy to achieve sustainability in the area.

Acknowledgements

This work has been supported by the WHO through the project "Digital assistive technologies" 2020.

Author details

Vivian Vimarlund[1,2*] and Diana Zandi[3]

1 Department of Computer and Information Science (IDA), Linköping University, Linköping, Sweden

2 Co-chair WG Ambient Assisted Living, IMIA

3 MScEE World Health Organization WHO, Geneva, Switzerland

*Address all correspondence to: vivian.vimarlund@liu.se

References

[1] WHO. The International Classification of Functioning, Disability and Health (ICF). Geneva: World Health Organization; 2001. Available from: https://unstats.un.org/unsd/demographic-social/meetings/2017/oman--disability-measurement-and-statistics/Session%205/UNSD_1.pdf

[2] Mort M, Milligan C, Roberts C. Chapter 1 healthcare at home? In: Ageing, Technology, and Home Care: New Actors, New Responsibilities. Paris: Presses des Mines; 2014. DOI: 10.4000/books.pressesmines1492

[3] United Nations, Department of Economic and Social Affairs, Population Division. World Population Ageing. 2015. (ST/ESA/SER.A/390)

[4] Blackman S, Matlo C, Bobrovitskiy C, Waldoch A, Fang ML, Jackson P, et al. Ambient assisted living technologies for aging well: A scoping review. Journal of Intelligent Systems. 2016;**25**(1):55-69

[5] WHO. World Report on Disability. Geneva: World Health Organization; 2011. ISBN: 9789241564182

[6] Foley A, Ferri BA. Technology for people, not disabilities: Ensuring access and inclusion. Journal of Research in Special Educational Needs. 2012;**12**(4):192-200. DOI: 10.1111/j.1471-3802.2011.01230.x

[7] Shengzhi W et al. Technology to support aging in place: Older adults' perspectives. Healthcare. 2019;**7**(2):60. DOI: 10.3390/healthcare7020060

[8] Vimarlund V, Borycki E, Kushniruk A, Avenberg K. Ambient assisted living: Identifying new challenges and needs for digital technologies and service innovation. IMIA Yearbook of Medical Informatics. 2021:16-34

[9] WHO. Policy Brief: Access to Assistive Technology. Geneva: World Health Organization; 2021 Available from: https://www.who.int/publications/i/item/978-92-4-000504-4

[10] United Nations Systems. A Shared United Nations System: Framework for Action Leaving No One behind. Equality and Non-Discrimination at the Heart of Sustainable Development. New York: United Nations; 2017 Available from: https://unsdg.un.org/2030-agenda/universal-values/leave-no-one-behind

[11] WHO. WHO Global Disability Action Plan 2014-2021. Better Health for all People with Disability. Action Plan 2014-2021. Geneva: WHO; 2015

[12] WHO. Global Cooperation on Assistive Technology (GATE). 2018. Available from: https://www.who.int/news-room/feature-stories/detail/global-cooperation-on-assistive-technology-(gate)

[13] Manzoor M, Vimarlund V. Digital technologies for social inclusion of individuals with disabilities. Health and Technology. 2018;**8**(5):377-390

[14] Webster J, Watson R. Analyzing the past to prepare for the future: Writing a literature review, MIS Quarterly. 2006;2: pp. xiii-xxiii

[15] Vimarlund V, Koch S. Identifying where the values come from IT-innovations in health and social care. Intelligent Information Management. 2012;**4**:296-308. Available from: https://www.researchgate.net/publication/232743185

[16] Smith E et al. Assistive technology use and provision during COVID-19: Results from a rapid global survey. International Journal of Health Policy and Management. 2020;**10**:1-10. DOI: 34172/ijhpm.2020.210

[17] Turing A. Can machines think? AI Magazine. 1992;**13**:2

[18] European Commission. Independent High-Level Expert Group on Artificial Intelligence. Set up by the European Commission. A Definition of AI: Main Capabilities and Disciplines. Directorate. General for Communications Networks, Content and Technology. Brussel: European Commission; 2019. Available from: https://digital-strategy.ec.europa.eu/en/library/definition-artificial-intelligence-main-capabilities-and-scientific-disciplines

[19] European Parliament. The Internet of Things Opportunities and Challenges, Briefing. European Union; 2015. Available from: http://www.eprs.ep.parl.union.eu (intranet)

[20] VanGrootven B, van Achterberg T. The European Union's ambient and assisted living. Joint programme. An evaluation of its impact on population health and well-being. Health Informatics Journal. 2016;**25**:27-40. DOI: 10.1177/1460458216683535

[21] Ramirez-Hernandez D, Stolwyk RJ, Chapman J, Dana WD. The experience and acceptability of smartphone reminder app training for people with acquired brain injury: A mixed methods study. Neuropsychological Rehabilitation. 2021;**2021**:1-28

[22] Pinard S, Bottari C, Laliberté C, Pigot H, Olivare M, Couture M, et al. Design and usability evaluation of COOK, an assistive technology for meal preparation for persons with severe TBI. Disability and Rehabilitation Assistive Technology. 2021;**16**(7):1-15

[23] Jamwal R, Callaway L, Farnworth L, Winkler DI. Electronic assistive technology use in Australian shared supported accommodation: Rates and user characteristics. Disability and Rehabilitation Assistive Technology. 2018;**13**(7):634-640

[24] Roopa M, Pattar S, Buyya R, et al. Social internet of things (SIoT): Foundations, thrust areas, systematic review and future directions. Computer Communications. 2019;**139**:32-57

[25] Radhhal M, Mirna AM, Ibrahim H. Health of humans and machines in a common perspective. Procedia Computer Science. 2020;**177**:415-422

[26] Rector K. Enchancing accessibility and engagement for those with disabilities. IEEE Pervasive Computing. 2018;**17**:9-12

[27] Weakley A, Tam JW, Van Son C, Schmitter-Edgecombe M. Effectiveness of a video-based aging services technology education program for health care professionals. Gerontology & Geriatrics Education. 2019;**40**(3):339-356

[28] Gagnon-Roy M, Bier N, Couture M, Giroux S, Pigot H, Zarshenas S, et al. Facilitators and obstacles to the use of a cognitive orthosis for meal preparation within the homes of adults with a moderate to severe traumatic brain injury: Informal caregivers and health-care professionals' perspectives. Assistive Technology. 2021;**4**:1-8

[29] Jamieson M, Cullen B, Lennon M, Brewster S, Evans J. Designing ApplTree: Usable scheduling software for people with cognitive impairments. Disability and Rehabilitation: Assistive Technology. 2020:1-11. DOI: 10.1080/17483107.2020.1785560

[30] Paunov C, Planes-Satorra S. What Future for Science Technology and Innovation after Covid-19? OECD Science, Technology and Industry Policy Papers. Paris: OECD Publishing; 2021 no 107. Rosemann M. Kowalielewicz M, Dootson P, Digital strategy of the future 2021. PWE Chair in. Paris: OECD Publishing;

[31] World Intellectual Property Organization. Technology Assistive Technology. Geneva, Switzerland: Trends; 2021

[32] Nordic Centre for Welfare and Social Issues Welfare Technology. 2010. Available from: www.nordicwelfare.org

[33] UNCTAD. Technology and Innovation Report 2021. Catching Technological Waves Innovation with Equity. Geneva, Switzerland: UNCTAD; 2021

[34] EU Fostering a European approach to Artificial Intelligence. Brussels 21, 4, 2021, Com (2021) 205 final

[35] Ambient Assisted Living & Smart Home Market Research Report by Product (Energy Management System, Entertainment Control, HVAC Control, and Security & Access Control), by Service (Customization & Renovation and Installation & Repair Service) - Global Forecast to 2025 - Cumulative Impact of COVID-19. Available from: https://www.reportlinker.com/p06025416/Ambient-Assisted-Living-Smart-Home-Market-Research-Report-by-Product-by-Service-Global-Forecast-to-Cumulative-Impact-of-COVID-19.html?utm_source=GNW

[36] Baert S, Lippens L, Moens E, Weytjens J, Sterkens P. The COVID 19 Crisis and Telework. A Research Survey on Experiences, Expectations, and Hopes. Global Labor Organization Discussion Paper N 532; Faculty of Economics and Business Administration. Ghent: Ghent University; 2020

[37] Chowdhury P, Paul SK, Kaisar S, Moktadir A. COVID-19 pandemic related supply chain studies: A systematic review. Transportation Research Part E: Logistics and Transportation Review. 2021;**148**:102271

[38] Chadoulos S, Koutsopoulos I, Polyzos G. Mobile apps meet the smart energy grid: A survey on consumer engagement and machine learning applications. IEEE Access. 2020;**8**:2169-3536. DOI: 10.1109/ACCESS.2020.3042758

[39] Alam MR, Reaz MB, Mohd Ali MA. A review of smart homes- past, present, and future. IEEE Transactions on Systems Man and Cybernetics Part C. 2020;**42**(6):1190-1203. DOI: 10.1109/TSMCC.2012.2189204

[40] Kim MJ, Cho ME, Jun HJ. Developing design solutions for smart homes through user-centered scenarios. Frontiers in Psychology. 2020;**11**:335. DOI: 10.3389/fpsyg.2020.0033

[41] Serrenho T, Bertoldi P. Smart Home and Appliances: State of the Art. Energy, Communications, Protocols, Standard. Luxembourg: European Union; 2019

[42] Cozza M, Crevani L, Hallin A, Schaeffer J. Future ageing: Welfare technology practices for our future older selves. Futures. 2019;**109**:117-129

[43] Budd J, Miller BS, Manning EM, Lampos V, Zhuang M, Edelstrin M, et al. Digital technologies in the public health response to COVID 19. Nature Medicine. 2020;**26**:1-10

[44] Ericsson LM. Consumer & IndustryLab. Keeping Consumers

Connected in a COVID-19. Ericsson Consumer & IndustryLab; 2020. Available from: https://www.ericsson.com/en/mobility-report/articles/connected-consumers-getting-through-the-pandemic

[45] Ejaz WM, Basharat M, Saadat S, Khattak AM, Naeem M, Anpalagan A. Earning paradigms for communication and computing technologies in IoT systems. Computer Communications. 2020;**153**:11-25

[46] Drigas A. Special education and ICTs. International Journal of Emerging Technologies in Learning. 2013;**8**(2):41-47. DOI: 10.3991/ijet.v8i2.2514

[47] Zhou Y, Rehman RZU, Hansen C, Maetzler W, Del Din S, Rochester L, et al. Classification of neurological patients to identify fallers based on spatial-temporal gait characteristics measured by a wearable device. Sensors. 2020;**20**(15):4098. DOI: 10.3390/s20154098

[48] Holzinger A, Errath M, Searle G, Thurnher B, Slany W. From extreme programming and usability engineering to extreme usability in software engineering education. In: 29th Annual International Computer Software and Applications Conference. Vol. 2. *COMPSAC IEEE*; IEEE; 2005. pp. 169-172

[49] Abdi S, de Witte L, Hawley M. Emerging technologies with potential care and support applications for older people: Review of gray literature. JMIR Aging. 2020;**3**(2):e17286. DOI: 10.2196/17286

[50] World Health Organization. Global perspectives on assistive technology. Proceedings of the GReaT Consultation, Vol 2. Geneva, Switzerland: WHO; August 2019;**2**:22-23