Sustainable Technologies for Older Adults

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Technology offers smart, sustainable solutions to enable older adults to live in better conditions. These solutions must cover not only healthcare, but also social and emotional needs in people's daily lives. Smart homes and cities, the IoT, ICT, robotic systems, artificial intelligence and other technologies can offer efficient, scalable, cost-effective and sustainable solutions. These solutions are not only accurate once cognitive or physical decline has become apparent but are also of great interest for the prevention and early detection of age-related decline.

Keywords: older adults ; sustainability ; technology ; readability ; Internet of Things ; sustainable development goals ; smart cities ; robotics ; gerontology ; health care

1. Introduction

Globally, life expectancy is increasing and society is aging. In 2019, there were 703 million people aged 65 years and it is estimated that in 2050 there will be 1500 million [1], representing 16% of the total population. Forecasts predict that in 2050, for the first time in history, the population over 65 years of age will outnumber the population under 10 years of age (**Table 1**). The reasons for these demographic changes vary, although the principal explanations are the reduction in the fertility rate and improvements in the probability of survival at advanced ages. This population aging will transform age-patterns of production and consumption and constitute a challenge for the sustainability of public pension systems. It is also estimated that the adult population will become a vulnerable group, being affected mainly by two of the 17 Sustainable Development Goals enacted by the UN General Assembly for 2030 [2]: Goal 1—No poverty and Goal 5—Gender equality.

Table 1. World population trends for under 10 s and over 65 s. Bold data indicates the outnumbering of the young population (source: [1]). Figures are expressed in thousands.

Location	Age	2015	2020	2040	2050
World	**<10**	**1,315,380**	**1,342,381**	**1,362,524**	**1,376,017**
	>65	**607,548**	**727,606**	**1,300,516**	**1,548,854**
Africa	**<10**	**346,678**	**381,403**	**496,260**	**545,328**
	>65	**39,729**	**47,096**	**97,501**	**143,103**
Asia	**<10**	**731,698**	**726,754**	**653,233**	**622,039**
	>65	**331,498**	**411,604**	**802,394**	**954,680**
Europe	**<10**	**80,088**	**79,821**	**68,157**	**69,258**
	>65	**130,515**	**142,905**	**188,280**	**199,896**
Latin America	**<10**	**105,561**	**103,887**	**91,447**	**85,470**
	>65	**48,356**	**58,651**	**113,560**	**144,623**
North America	**<10**	**44,857**	**43,706**	**46,069**	**46,153**
	>65	**52,787**	**61,901**	**89,894**	**96,278**

Table 2 shows the poverty levels of older adults in the most populated OECD countries according to the OECD report Pensions at a glance: OECD and G20 Indicators [3]. People are considered to be in poverty if they have an income that is less than half of the national mean equivalized disposable household income. The data show how poverty is more frequent among the elderly and the gap is wider when we consider gender. Older women are poorer than older men.

Table 2. Percentage of income poverty in older adults in the most populated countries in the OECD (source: [3]).

Country	Percentage of Total Population Living in Poverty	Older Adults Poverty (All)	Older Adults Poverty (Male)	Older Adults Poverty (Women)	Difference Total vs. Older Adults	Genre Difference
China	28.8	39	37.9	40.1	10.2	2.2
Mexico	16.6	24.7	23.3	25.9	8.1	2.6
United States	17.8	23.1	19.6	25.9	5.3	6.3
Japan	15.7	19.6	16.2	22.3	3.9	6.1
United Kingdom	11.9	15.3	12.5	17.7	3.4	5.2
India	19.7	22.9	21.9	24	3.2	2.1
OECD	11.8	13.5	10.3	15.7	1.7	5.4
Russia	12.7	14.1	8.4	17	1.4	8.6
Turkey	17.2	17	14.9	18.5	−0.2	3.6
Germany	10.4	9.6	7.4	10.6	−0.8	3.2
Brazil	20	7.7	7.5	7.8	−12.3	0.3

To mitigate the macroeconomic impact of this population aging, the UN proposes promoting lifelong learning systems, extending health care to the entire population, encouraging healthy lifestyles, advocating savings, improving the employability of the elderly, avoiding the gender gap, delaying the retirement age and improving family reconciliation [1].

The United Nations defines sustainability in a broad sense, as actions to meet the needs of the present without compromising the ability of future generations to meet their own needs. Under this premise, the UN proposed the sustainable development goals as actions and priorities to be carried out in order to reduce poverty, improve health and education, reduce inequalities, grow economically, preserve nature and reduce the risk of climate change [2]. Achieving sustainable development goals requires addressing three essential challenges: economic, social and environmental. **Table 1** and **Table 2** show data concerning sustainability problems. It is clear not only that the elderly will in the future take on greater sociodemographic importance, but also that there is a problem of economic insufficiency, especially in relation to the female gender. Technologies to tackle these problems should thus address the aspects of population growth, poverty and gender.

One factor that cannot be ignored is the impact of aging on health. Low fertility and mortality rates have not only a demographic but also an epidemiological impact. In the coming years, diseases will be more closely linked to aging populations with greater resources. By 2030, the WHO [4][5] has predicted increases in heart disease, cancer and diabetes, and decreases in perinatal mortality, parasitic infections and malnutrition. Mobility impairment and dementia will follow a pattern of growth, especially in countries with fewer resources. According to the aforementioned report, in developed countries 30% of the elderly over 85 and 50% of those over 90 suffer from dementia. Older adults face conditions that may have been acquired during the course of their lives, such as brain injuries or dementia. Aging increases the risk of dementia, the most common cause of which is Alzheimer's disease (70%), with symptoms such as forgetfulness, temporal and spatial disorientation and communication difficulties. According to the Ageing Report, in 2050 one third of the European populations will be over 65 years old. The WHO [6] estimates that 5–8% of this population will suffer from dementia. In this regard, ageism (discriminatory attitudes towards certain age groups) is growing. The data show that ageism has a negative impact on the health of older adults. In [7], prevalence of this prejudice was estimated to affect 50% of the population.

The economic impact of declining health and decreasing retirement ages is a growing concern. Deteriorating health coupled with increased longevity requires long-term care. The experience gained, the existence of less strenuous jobs and the likelihood of reaching old age while maintaining good health mean that retirement policies must be evaluated. Another aspect worthy of consideration is loneliness; support for families would benefit both families and older adults. Despite this fact, the number of people living alone, in institutions or alone with their spouse has increased in recent years. All these aspects can be improved by keeping the elderly healthy for longer.

2. Sustainable Technologies for Older Adults

Sustainable technology in older adults could be grouped into three different categories dealing with different aspects of the daily life of older adults: (1) eHealth, which includes papers related to disease prevention, detection and treatment, tele-health and health applications, among other issues; (2) daily activities and wellbeing, which includes different kinds of activities performed by older adults in their daily lives, such as education and training, leisure time, social communication and physical and emotional well-being; (3) policies and strategic plans, which includes technology related to global and systematic strategies affecting older adults, such as environmental or financial sustainability, sustainable living and transport.

2.1. eHealth

Table 3 summarizes the main trends, strengths and weaknesses of using sustainable technology for eHealth and elderly life.

Table 3. Sustainable Technology in eHealth.

Domain of Application	SQ1 Main Research Areas Addressing Older Adults	SQ2 How Technology Is Used and for What Purposes	SQ3 Extent in Which Technology Contributes to Sustainability	# Papers	References
e-Health Actions related to illness prevention, detection and treatment	**Monitor patients to detect clinical conditions or send messages to improve treatment adherence Data mining, ML and LA with different purposes: detect patterns globally or automate alarms and personalized messages to patients in key situations for their health. Medical assistance, emergency support and disability support**	**IoT to sensor and monitor patients in different situations: (1) monitor specific parameters for detection and control of specific pathologies such as diabetes, heart problems. (2) monitor emergency situations such as falls, heart attacks or stroke. Digitalization of medical records ML and LA to analyze data and provide alarms that trigger services based on data from IoT devices or medical records. Assistive robotics to support physical problems derived from an acquired disability or mobility limitations typical of aging (e.g., wheelchair, exoskeleton or robotics arms).**	**Big data techniques improve pattern detection and personalization of services and allow the application of ML and LA techniques on a larger scale. Improving communication among professionals from different services allow the attendance of pluri-pathological patients Improving the accessibility and usability of HW and SW (computers, mobile phones and specific devices) allows its application to larger groups with special needs, such as the elderly.**	**27**	**[8][9][10][11][12][13][14][15][16][17][18][19][20][21][22][23][24][25][26][27][28][29][30][31][32][33][34][35]**

2.1.1. eHealth and Information and Communication Technologies

In the field of medicine, Information and Communication Technologies (ICTs) are used to create sustainable conditions aimed at improving the quality of life of older adults and mainly related to illness prevention, detection and treatment. Information and Communication Technologies include mobile or desktop applications. Improvements in healthcare have significantly benefitted the population, above all older adults and their families.

One example of using technology for illness prevention is the initiative to implement immunization triage programs in an emergency department to achieve a sustainable system, reported in [8]. This work examined whether information technology provided a viable, sustainable method for increasing vaccination rates in an adult emergency department. The computerized reminder system produced positive results by increasing vaccination rates.

With regard to the treatment of illness, Information and Communications Technology is one of the most successful technologies for facilitating home healthcare and telemedicine. The aging population impacts all areas of society, putting pressure on social expenditures and public health services and raising the number of challenges in medical care and rehabilitation. In [14], e-health is presented as a promising concept supporting the idea of independent living for patients with chronic diseases. In regions with older populations that have to travel long distances to hospitals or medical centers, services are improved by technology, but each patient needs personalized treatment.

Some of the difficulties posed by chronic disease self-management tools are discussed in [16]. One of the biggest problems is that such tools are usually designed for a single disease and do not take into account the fact that elderly people usually have multiple pathologies. Another issue is usability: most tools have not been designed with the specific needs of the elderly in mind. Kastner presented an eHealth self-management application called 'KeepWell' capable of supporting seniors with complex care needs in their homes and proposed a trial to validate its efficacy, cost and acceptance.

2.1.2. eHealth and the Internet of Things

Sensor-enhanced health information systems play an important role in creating sustainable conditions for self-sufficient and self-determined lifestyles [18].

Healthcare providers are turning to sustainable technological solutions capable of facilitating information exchange for mobile geriatric care [19]. The use of IoT devices with multiple sensors allows doctors to perform medical check-ups regularly, receiving data directly from the devices and analyzing it accordingly even when they are not in the same building as the patient.

2.1.3. eHealth and Smart Living

Smart living technologies can facilitate interaction between health personnel and older adults. This category of technologies includes things such as Ambient Assisted Living and smart homes or cities. Of particular interest is the development of spoken language-based applications, which provide an intuitive, accessible interface for both the elderly and their home care providers [23]. In this type of AAL technology, it is recommended that informal caregivers, as experts in the matter, be taken into account when designing such tools [24].

Several studies focused on improving the life quality of older adults in their own homes, avoiding the need to travel to healthcare centers by using different devices to monitor their needs and medical parameters [25]. Some researchers are developing devices using machine learning which can track health parameters through urine tests, measure blood pressure etc. [26][27].

2.1.4. eHealth and Artificial Intelligence and Big Data Technology

Fuzzy-semantic systems have been developed to evaluate the physical state of patients during the rehabilitation process [28]. These kinds of systems are used in mobility/rehabilitation therapies, where the relationship between older adults' mobility and their quality of life is well documented.

2.1.5. eHealth and Robotics and Cybernetics

Robotic solutions are now being designed to provide support for daily activities performed by older adults. Ref. [29] proposed a taxonomy of social robotics, identifying 3 main categories: (i) Assistive Robotics (AR), which gives aid or support to a human user (rehabilitation, wheelchair and other mobility aids, companion robots, manipulator arms for the physically disabled and educational robots). (ii) Socially Interactive Robotics (SIR), the main goal of which is to develop close, effective interactions with a human for the sake of interaction itself. (iii) Socially Assistive Robotics (SAR), which also aims to create close, effective interaction with humans but in this case in order to assist and achieve measurable progress in convalescence, rehabilitation, learning, etc.

Different robots have been successfully used in caring for older adults to prevent dementia. The study carried out by [30], for example, described a robot programmed to play chess to combat brain degeneration.

2.1.6. eHealth and Serious Games and Gamification

Health care associated with leisure time has brought important benefits to the population. One interesting proposal is that of gaming platforms. In 2018, Valenzuela [35] reported how gamification was applied to increase engagement and effectiveness. The author conducted a literature review to show that persistence and participation in the use of fitness games (or exergames) increased when they were more enjoyable.

2.2. Daily Activities and Well-Being

Table 4 summarizes the main trends, strengths and weaknesses of using sustainable technology for daily activities and wellbeing.

Table 4. Sustainable technology for daily activities and wellbeing.

Domain of Application	SQ1 Main Research Areas Addressing Older Adults	SQ2 How Technology Is Used and for What Purposes	SQ3 Extent in Which Technology Contributes to Sustainability	# Papers	References
Daily activities and wellbeing Actions oriented to facilitate autonomy of elderly helping them to perform every day actions on their own.	Monitor patients in their daily routines: physiological needs, physical activity and nutrition. Mental wellbeing fostering communication, learning and gamification Digital literacy to use personal devices (mobile phones, computers and wearables) to support physical and mental wellbeing	IoT and big data to sensor and monitor patients in different situations to promote active and healthy aging Commercial wearables (wristbands, pedometer, mobile phones) with IoT sensors integrated to monitor patients and send them alarms Socially interactive or assistive robotics for emotional support or to prevent dementia. Even though there are many successful prototypes, the technology is not yet mature for mass and sustainable use Gamification with different purposes: learning, mental activity, physical activity or daily routines.	Interoperability and usability of IoT systems and battery duration still need substantial improvement to make some of these technical solutions sustainable. The maturity of educational platforms (MOOCs, LMS) has made it possible to bring education and serious games to this group despite their mobility problems. Increased use of social networking and videoconferencing tools have allowed elderly to stay connected with family and friends, support networks such as neighborhood centers and health services.	47	[20][34][36][37][38][39][40][41][42][43][44][45][46][47][48][49][50][51][52][53][54][55][56][57][58][59][60][61][62][63][64][65][66][67][68][69][70][71][72][73][74][75][76][77][78][79][80][81]

2.2.1. Daily Activities and Information and Communication Technologies

With respect to technology oriented to older adults, Ref. [39] proposed habilitating the home or community environment to enable older adults to remain active and independent for longer through mind stimulation measures that included interactive television and personalized ICT support. This approach proposed the use of open standards, low-cost solutions and interoperable applications.

Carretero [40] demonstrated the benefits of employing ICT-based services for informal caregivers and attendants, in terms of sustainability and savings for the care system. This idea was supported by Leslie et al. [41], whose study focused on how technology can help family caregivers work more sustainably and aid resilience. These authors found that caregivers need improved computer systems capable of connecting them and providing information and support.

2.2.2. Daily Activities and the Internet of Things

Many authors highlight the importance of sensors for monitoring physiological signals and of the Internet of Things (IoT) as an aid to independent aging [20][42][43][44][45][46] compiled several IoT applications, protocols and methods for elderly people and people with special needs. With regard to IoT, the study by [47] addressed digital services for the 60–75 age group by digitally adopting wellness routines. This study found that in this group routines are not maintained over time and concluded that digital coaching can help users create good, effective, sustainable wellness routines. Prominent in this group of articles are those related to fall detection systems for elderly people [48][49]. These systems monitor and detect critical events such as injuries or dangerous environments, triggering immediate action and response.

2.2.3. Daily Activities and Smart Living

As can be seen in the keyword analysis, smart cities and smart homes account for a large amount of research. Some authors [56][57] have proposed different approaches for implementing smart eldercare and sustainability. Ref. [58] proposed smart senior citizens' communities, using technology as a sustainable method with which to support the aged and incorporating the brand new "green" practice of modern communities.

However, all these technologies do more than simply make it possible to monitor people's lives in order to improve living conditions and prevent problems associated with aging. They also help reduce the effect of adverse events such as falls. Ref. [62], for example, investigated how shock-absorbent flooring in wards for older adults reduces fall-related injuries.

Ambient Assisted Living is a sustainable, affordable solution that allows older adults to lead independent lives. Some studies have tried to identify the main challenges of applying AAL for independent living. In a survey carried out with specialists to learn more about the main problems of this approach, Ref. [63] found problems of reliability, robustness, security and data privacy.

Ambient Intelligence Living (AML) is a paradigm related to AAL. In AML, sensors and wearables are integrated into our everyday environment, the data being processed with Artificial Intelligence (AI). Older adults need constant monitoring to control their health status and quality of life. In this case, the main problem is to find the best way to interconnect devices.

2.2.4. Daily Activities and Artificial Intelligence and Big Data Technology

Human Activity Recognition (HAR) is a well-known problem when using technologies such as ICT or IoT for eldercare and healthcare. Activity is usually detected with the help of sensors, smartphones or imaging devices. However, the data acquired is meaningless if it is not analyzed. Jobanputra and colleagues [71] presented a survey of different operational Artificial Intelligence techniques and methods and compared their results. The technologies studied included Decision Trees (DT), K-nearest Neighbours (KNN), Support Vector Machines (SVM), Hidden Markov Models (HMM), Neural Networks as Convolutional Neural Networks (CNN) and Recurrent Neural Networks (RNN).

2.2.5. Daily Activities and Robotics and Cybernetics

One way to reduce caregiver dependency is to detect those repetitive daily tasks that can be automated, such as taking medications. Chen [73] designed a smart medication dispenser with a friendly human-computer interaction interface that prevents patients from forgetting their medication and also avoids other errors such as skipping doses. The interesting multidisciplinary project Robot Companions for Citizens [74] proposed an innovative design for more adaptive, behaviorally complex robotic systems capable of assisting older adults with their everyday needs. This initiative combined nanotechnology, biomaterials, neuroscience and human-robot and robot-robot interaction. In the social domain, one equally innovative application of robotics focuses on creating social networks between humans and robots (human-robot social interactions—HRSI).

One of the key requirements for creating sustainable adult-robot relationships is to improve affective exchanges between humans and robots. Reference [34] proposed introducing a human-robot affective dimension to improve the acceptability of robotic systems. This included non-intrusive sensory interfaces that adapt robot's affective responses to the user's behavior, using verbal and non-verbal communication to enhance the empathic exchange of moods and feelings.

The application of robotics, however, goes beyond merely considering robots as isolated individuals that provide support at specific moments. Studies also exist in which the robot is integrated more closely with the user to provide support in certain activities. Ref. [76], for example, presented a robotic exoskeleton for gait assistance that facilitates active aging by reducing oxygen consumption in comparison with treadmill walking or self-paced overground walking at the same speed. One of the main drawbacks of such gait assistance exoskeletons is that they tend to be large and heavy.

2.2.6. Daily Activities and Serious Games and Gamification

One of the purposes for which serious games have most frequently been applied as a means of enhancing the quality of life in active aging has been to improve cognitive function. Cognitive impairment and dementia are two of the main threats in this area. These types of interventions, referenced using the umbrella term Computerized Cognitive Training (CTT), consist of systematic, repetitive exercises performed on different platforms (computer games, mobile devices, gaming consoles and virtual reality) to improve specific cognitive domains. Even though much research has been carried out in this area, the studies vary greatly and are not very repeatable. Ref. [79] conducted a systematic review of the literature for interventions lasting 12 weeks or more. Among its main findings, CTT was found to slightly improve global cognitive function compared with other active interventions such as the viewing of educational videos, and there was evidence of a slight improvement in episodic memory compared to inactive control groups. However, no changes in processing speed were detected, nor was there any significant evidence that the cognitive improvements detected persisted over time. It is therefore important to point out that this is an open, active field of research and that more investigation, with more extensive and more in-depth studies, is needed to obtain conclusive results that will scientifically demonstrate the long-term benefits.

2.3. Policies and Strategic Plans

Table 5 shows a summary of the main policies and strategic plans of using sustainable technology for elderly life.

Table 5. Sustainable Technology for Policies and Strategic Plans.

Domain of Application	SQ1 Main Research Areas Addressing Older Adults	SQ2 How Technology Is Used and for What Purposes	SQ3 Extent in Which Technology Contributes to Sustainability	# Papers	References
Policies and Strategic Plans Actions oriented to facilitate the provision of public health, mobility, education and wellbeing services in general and guarantee their sustainability over time.	Create ecosystems with smart facilities and ambient assisted living: smart cities, smart mobility, smart home. Empower users and focus on prevention rather than clinical intervention. Promote individual's autonomy, peer led and social support networks. Considering users, their needs and limitations and involving them in the design of services is key to achieving mass adoption of easy-to-use products and services.	Big data to monitor users, products, services and systems, detect patterns and make predictions. The massive use of cell phones and the increasing penetration of wearables have provided a large part of the population with tools that can be used for monitoring and communication, but it is necessary to make progress in the privacy and security of the data exchanged. One of the main challenges is the interoperability among platforms, devices and data to achieve common infrastructures for the whole ecosystem. It is also important to reduce cost and improve energy efficiency and device's lifetime. to provide low-cost products and services.	It is necessary not to focus on partial solutions to very specific problems but to create a global ecosystem that monitors, connects and informs the needs of different stakeholders: policy makers, healthcare providers, social services, technological industry and individuals using product-service-systems approach. Scale economy and TIC support in in the most disadvantaged areas, such as rural areas or developing countries. New ways of distance product and service delivery that considers usability issues in elderly collective.	46	[24][44][61][82][83][84][85][86][87][88][89][90][91][92][93][94][95][96][97][98][99][100][101][102][103][104][105][106][107][108][109][110][111][112][113][114][115][116][117][118][119][120][121][122][123][124][125]

2.3.1. Policies and the Internet of Things

One efficient, sustainable way to help older adults live independently is the use of wearables. A literature review conducted by Godfrey in 2017 [97] on the use of wearables to track older adults' movement (or gait analysis) revealed a great variety of types but threw little light on how they work. Some studies have highlighted the potential energy saving advantages of certain disease prevention measures. Ref. [98], for example studied using the IoT to save energy in lighting while minimizing eye strain in smart homes.

Rich and colleagues [99] described peer-led physical activity interventions with 408 adults in 12 ethnically diverse senior centers in San Diego County. Wearables and sensors (pedometers, wrist activity monitors, blood pressure, GPS devices) were used to monitor individuals and tablets were used by peer health coaches to deliver and track the intervention. One of the main findings was that using a peer-led implementation strategy to deliver technologically monitored physical activities can enhance the adoption, implementation and sustainability of programs.

In Taiwan, the IoT was integrated into the Agricultural and Livestock Production Management System in order to achieve the goal of sustainable agriculture [100]. An agricultural product traceability system made it possible to check compliance with product quality requirements. However, many farmers in Taiwan are small-scale farmers and/or elderly citizens who do not habitually use computers and find it difficult to send the data required to the traceability system. The IoT system allowed the system itself to create real-time production data and send it directly to the traceability system, so the farmers did not need to learn to use computers to upload data to the quality system.

2.3.2. Policies and Information and Communication Technologies

The LivingLab PJAIT project [92] presented a sustainable ICT-based solution to improve senior citizen participation in urban life based on lowering ICT barriers, promoting social inclusion and engaging older adults in the process of developing ICT solutions.

Research into technology aimed at older adults has also explored energy efficient, friendly technologies for mobile and portable devices such as video transmission devices [93]. The aim is to increase such devices' lifetimes. Energy efficiency and user-friendliness are essential in technologies, so reducing power consumption in devices [49] and improving the lifetime and reliability of batteries [94] are key objectives. It is assumed that energy efficiency and resource sustainability will result in improvements in both the service provided by workers and the service received from citizens.

The concept of smart mobility understood as the use of ICTs to organize shared transport adapted to people's individual needs has traditionally been associated mainly with urban environments. However, there are some studies that have analyzed the benefits of adopting this approach also in rural areas. One of these, conducted by [95] in Heinsberg, a rural region in the west of Germany, revealed that smart mobility can help alleviate several disadvantages of rural living, including shortcomings in the provision of public transport supplies and restrictions in older adults' access to different amenities.

2.3.3. Policies and Smart Living

ICTs applied as part of a multidisciplinary approach to an area of knowledge such as this may have a greater impact, because they make it possible to respond to users' needs while at the same time providing information on users' daily behavior, thus helping to better manage the sustainability of the system as a whole. In this regard, Ref. [101] proposed a Product-Service-System approach for integrating ergonomics and sustainability competences in the development of Ambient Assisted Living, an initiative based on the research experiences of the Technology and Design for Healthcare (TeDH) research group in the INDACO (Industrial Design, Communication, Arts and Fashion) department at the Polytechnic University of Milan.

2.3.4. Policies and Artificial Intelligence and Big Data Technology

Urban planning can have both positive and negative effects on the health, well-being and social participation of a city's inhabitants. However, the decisions made by stakeholders involved in public services must be based on firm evidence. Advances in the IoT, LA and big data can contribute significantly to the collection and processing of such evidence. The INTERACT (Interventions, Research and Action in Cities) project [104] involved natural experiments in 4 Canadian cities. This project not only delivered timely evidence about how urban interventions influence health and wellbeing but also took a step forward in this direction by providing methods and tools to facilitate such studies. To address these challenges, the project team plans to collect around 100TB of sensor data on both location and physical activity over 5 years.

2.3.5. Policies and Robotics and Cybernetics

Twenty years ago, there were great expectations about what ideal multitasking robots for assisting the elderly would appear in the future. Despite much research along these lines, however, their use today remains marginal. Reference [106] pointed out that one of the main reasons for this is the fact that research is carried out on imaginary scenarios or in small-scale trials. She also noted that for robotic solutions to be useful, affordable and sustainable from an ethical, social and ecological point of view, research proposals must be evaluated within the framework of existing care ecosystems, taking into account the real political and economic contexts in which care is provided and the provision of care when resources are limited.

Reference [107] provided a glimpse into the future of elder care, reinforcing Van Aerscot's idea of the need for a more comprehensive approach involving institutions. A transition in the elder care system was predicted, with robots ultimately being embedded in welfare services and society. The authors focused on the future of elder care and how it will be affected by the emergence of care robotics, taking the current use of robots in elder care as a point of departure. The study's results established that there is a shift towards the use of robots in care, but that socio-institutional and technological adaption is needed. These two areas are highly interrelated and both of them need to be taken into account for the successful integration of robots in society.

2.4. Transversal Aspects of Technology

The transversal aspects of technology affect all areas, including: (1) design methodologies; (2) the usability and accessibility of the applications implemented; (3) understanding of behavioral patterns in the target population; (4) interaction between the different stakeholders affected by applications; and (5) training in the use of technology.

- Design methodology. User-centered, inclusive, co-creative design methodologies are recommended for developing successful, sustainable technologies. Reference [24] recommended engaging informal caregivers, as experts, in the design of AAL-related technologies. In the same vein, Ref. [108] studied how older adults can participate in the software development process, to produce more friendly, useful applications for this population. Reference [109] reported how an IoT for Seniors course led to the design of more suitable applications by developers [108].

- Usability and accessibility features. To make technology sustainable, it must be developed taking into account characteristics such as usability (including efficiency, effectiveness, easy-of-use, user satisfaction, etc.) and accessibility (creating technologies—including mainstream and assistive solutions—that everyone, including older adults and people with disabilities, can use in a range of different contexts) [110].

- Behavioral patterns. As part of the requirements acquisition phase in technology design methodology, it is important to consider users' behavioral patterns. Some papers have described surveys conducted to see how older adults relate to their environment and to technology, to allow the development of more accessible software and devices for use by this group [108][109].

- Stakeholder interaction. Interaction and communication between all the different agents involved can contribute to a technology's success. In [119] the design of a multidisciplinary clinical pathway to treat hip fractures reduced mortality rates and shortened hospital stays.

- Training in the use of technology. ICTs offer many possibilities for improving the daily lives of adults, but the digital divide can also be a factor of social exclusion for them.

However, the elderly population should not be seen only as the recipients of educational actions. In a society where life expectancy is increasing, the contribution of the elderly is a valuable resource that needs to be leveraged. In this avenue of research, Ref. [122] proposed the digital inclusion of elderly groups through a participatory process of digital tool co-creation. This work illustrated the appropriation of digital skills by including older adults as content co-creators in a MOOC (Massive Open Online Course) about how to promote active life for older adults through a collaborative economy. This type of collaboration proved to be effective not only in improving the quality of MOOC content, but also in adapting tools for different groups and improving the autonomy of the groups involved.

2.5. The Process of Technology Adoption in The Elderly

2.5.1. Technology Adoption

One of the main limitations when implementing programs for independent living for older adults is their reluctance to use technology. Fields et al. [126] reported that one-third of older adults do not use the internet. This rejection contrasts with the undoubted benefits of the internet for this group: connectivity versus loneliness and a more sustainable health care system. Concern in this regard is aggravated by the shortage of care workers. Basically, the sustainability of health care systems needs technology capable of overcoming these difficulties.

The rejection of technology has been discussed in papers such as [114]. It is an attitude perfectly illustrated in the work carried out by [127] in the field of Information Science. The aforementioned researchers used semi-structured interviews and focus groups to study the impact of information and communication technologies (ICT) in public access venues (PAV) in Botswanan libraries with Internet connections. Their results revealed differences in the acquisition and use of computer skills between users who attend school and users who do not attend school. Older users who do not attend school tend to rely on site staff for information and services, avoiding computing terminals. Another paper worth mentioning is that of [128]. This work, related to the COVID-19 pandemic, studied how centers for the elderly have tried to maintain their services by replacing them with online activities. The study tried to determine whether such online activities are an appropriate substitute for in-person activities. A survey was conducted among 105 older adults. Participants in the activities tended to be very satisfied. Non-participants justified their non-involvement with reasons such as: ignorance of the web-based program, lack of interest in the content and problems. The study concluded that there was a need for web-based activities to counteract issues of boredom and feelings of isolation and for current programs for older adults to be made more accessible.

2.5.2. Training in the Use of Technology

The lack of computer skills is a major challenge for elderly people. To tackle this problem, many projects have been implemented aimed at increasing senior citizens' computer skills. One such project was OASIS [129]. Fields et al. [126] observed a positive effect of providing in-home digital training for older adults in terms of social support and the more confident use of technology. One particularly innovative study was carried out by Ha et al. [130]. Its aim was to detect barriers to the delivery of distance geriatric training between two countries, Singapore and Uganda. Cross-cultural education via videoconferencing was proven to be feasible, although recommendations will need to be designed.

2.5.3. Long-Term Use and Limitations to the Use of Technologies

Another intriguing area of study affecting the development of sustainable technologies for the elderly is the analysis of factors that cause older adults to discontinue their use of these technologies. Here, it is particularly important to study variations in the use of technologies in the medium and long term. Long-term use and older adults' attitudes towards computers were analyzed in the DITUS project [131]. The same results were obtained by Fields et al. [126] and Pasalich et al. [36]. In the same vein, Ref. [132] studied how ICTs can help family members to continue the healthy living practices they engaged in when they lived together. The authors proved that in families which engage in healthy living practices together,

all the family members (regardless of age) have a better and higher quality of life. The use of technology to communicate and support members living apart and to cultivate health habits help them to effectively collaborate in healthy living.

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