

Article

Socially Assistive Robots in Smart Environments to Attend Elderly People—A Survey

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Abstract: The aging of the population in developed and developing countries, together with the degree of maturity reached by certain technologies, means that the design of care environments for the elderly with a high degree of technological innovation is now being seriously considered. Assistive environments for daily living (Ambient Assisted Living, AAL) include the deployment of sensors and certain actuators in the home or residence where the person to be cared for lives so that, with the help of the necessary computational management and decision-making mechanisms, the person can live a more autonomous life. Although the cost of implementing such technologies in the home is still high, they are becoming more affordable, and their use is, therefore, becoming more popular. At a time when some countries are finding it difficult to provide adequate care for their elderly, this option is seen as a help for carers and to avoid collapsing health care services. However, despite the undoubted potential of the services offered by these AAL systems, there are serious problems of acceptance today. In part, these problems arise from the design phase, which often does not sufficiently take into account the end users—older people but also carers. On the other hand, it is complex for these older people to interact with interfaces that are sometimes not very natural or intuitive. The use of a socially assistive robot (SAR) that serves as an interface to the AAL system and takes responsibility for the interaction with the person is a possible solution. The robot is a physical entity that can operate with a certain degree of autonomy and be able to bring features to the interaction with the person that, obviously, a tablet or smartphone will not be able to do. The robot can benefit from the recent popularization of artificial intelligence-based solutions to personalize its attention to the person and to provide services that were unimaginable just a few years ago. Their inclusion in an AAL ecosystem should, however, also be carefully assessed. The robot's mission should not be to replace the person but to be a tool to facilitate the elderly person's daily life. Its design should consider the AAL system in which it is integrated, the needs and preferences of the people with whom it will interact, and the services that, in conjunction with this system, the robot can offer. The aim of this article is to review the current state of the art in the integration of SARs into the AAL ecosystem and to determine whether an initial phase of high expectations but very limited results have been overcome.

Keywords: socially assistive robotics; Ambient Assisted Living (AAL); monitoring



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1. Introduction

Population aging is already a reality in large parts of the world and is bringing about a profound demographic change. Thus, taking into account the population as a whole (not just the over-64s), globally, the number of workers per older person will fall from 7 in 2015 to only 4.9 in 2030. In Western European countries, it will go from 3.5 workers per older person in 2015 to 2.4 in 2030 [1]. The numbers are even more dramatic in Japan: the ratio of the working-age population (aged 15–64) to the older population (65 and over) decreased from 7.4 persons of working age per older person in 1980 to 2.1 by 2020 [2]. Thus, it is estimated by the Government of Japan that there will be a shortage of 370,000 nurses

and care professionals to accommodate this older demographic by 2025 [3]. Given these figures, the near future will require greater investment in health and social resources for older people. At the same time, the percentage of health professionals and temporary carers who can assist the elderly in their daily lives will be reduced. To cope with these changes, as indicated in the European SPARC report [4], it will be necessary to design and implement new multidisciplinary models and action plans, integrating therapeutic, social, or technological measures, with the aim of ensuring well-being in society. Within these plans, the concept of active aging emerges as a key element, defined as “the process of optimizing opportunities for health, participation, and security to improve quality of life as people age” [5]. According to the active aging criteria, people should try to remain as independent and active as possible for as long as possible. This policy aims to increase the person’s sense of well-being and to maintain him/her as an asset to society [6], but also to reduce the costs of care or institutionalization, which is delayed or even avoided. In order to implement active aging policies, it is necessary to ensure adequate protection, security, and care for people [5]. This involves personalized treatment, long-term follow-up, including continuous assessment of the person’s capacities, and the use of monitoring, communication, and therapy technologies, both at home and in hospitals, nursing homes, or daycare centers (hereafter referred to as nursing homes). The objective is the development of environments in which “individuals can expect to age actively” [6]. These technologies for active aging, encompassed under the term Ambient Assisted Living (AAL) [7], emerge to contribute to the independence of older people, but also to alleviate the workload of healthcare professionals and caregivers, without replacing them in any case.

1.1. Ambient Assisted Living

AAL technologies encompass a wide variety of systems and applications in multiple contexts. Focusing on the application of such technologies in the care of the elderly and taking into account the views of healthcare professionals, end users, and family members [8], it is possible to establish three key objectives for AAL in this context: (1) to increase the safety of end users; (2) to contribute to their autonomy; and (3) to reduce the workload of caregivers and healthcare staff. The achievement of these objectives is fundamentally associated with the integration of monitoring technologies in the elderly person’s environment [8], which allow the automatic detection of any emergency, as well as the rapid checking of the person’s condition and location. These monitoring systems are joined by other systems that allow an older person to communicate with family and friends, care staff, external experts, or other residents. There are also systems that apply technology for therapeutic purposes, including mechanisms for rehabilitation exercises or Comprehensive Geriatric Assessment tests, systems for motivation and reminders of healthy living practices, “serious” or educational games, or systems for cognitive support and reinforcement of prospective and retrospective memory [7,9].

1.2. Socially Assistive Robots

In terms of choosing the most appropriate AAL technologies, in principle, those that allow the automation of processes, minimize the need for supervision, and allow different applications and systems to be managed using the same interfaces will be more relevant. In this context, a versatile, motivating, and powerful tool appears and gains relevance within the AAL ecosystems, both in terms of assisting the elderly person and helping the caregiver. This tool is the socially assistive robot or SAR for short. According to Feil-Seifer and Mataric [10], a SAR is the intersection between an assistive robot and a socially interactive robot. It shares with the assistive robot the goal of providing assistance to a human user but specifies that the assistance is provided through social interaction [11]. This definition includes rehabilitation robots, autonomous wheelchairs, robotic manipulators, educational robots, or companion robots. In this sense, it could overlap with other domains of robotics in the healthcare field. The difference, however, lies in the domain in which these robots are used [4]. SARs are intended to be used by generally healthy people in

everyday environments that are not necessarily healthcare (home, city, elderly people's residence, ...), and in a more autonomous way, not requiring continuous and direct control by a healthcare worker or caregiver. In fact, SARs are not classified as healthcare robotics but as consumer, robotics [4]. They are conceived as a key part of facilitating independent living at any age and innovating society towards inclusion and active aging. In this task, they cooperate with other technologies such as healthcare robotics, the smart home, or, in general, AAL ecosystems, in which they are naturally integrated [4,12].

Among the advantages that SARs offer over other technologies is the fact that they are designed to work in everyday environments that are neither controlled nor predictable [10]. Thus, they must be inherently versatile to incorporate new functionalities and act as an interface between a person and an intelligent environment, providing an appropriate and adapted response to the user [12]. Moreover, a socially assistive robot does not need physical contact with the person to fulfill its function. This considerably reduces the risks in human-robot interaction [10,11] and facilitates their commercial deployment [4].

Although the advantages of combining AAL systems and robots seem clear [13], it seems necessary from this background to analyze the degree of acceptance and usefulness of an AAL ecosystem using a SAR when such an ecosystem has been designed with the user in mind. It should also establish a relationship between the capabilities of an AAL ecosystem with an assistive social robot and its short-, medium- and long-term acceptance and provide a framework for long-term experiments with assistive social robots in AAL ecosystems. Such experiments should be conducted in real environments, thoroughly documented, and reproducible. The aim of this paper is to provide a snapshot of the current deployment of SAR in AAL ecosystems to assist older people in their homes or nursing homes.

1.3. Organization of the Manuscript

The rest of the paper is organized as follows: Section 2 explains the literature review process. Results are presented in Section 3. Discussion is provided in Section 4. Finally, conclusions and future work are drawn in Section 5.

2. Methodology

This section describes the criteria used both to select the set of articles considered for this review article (Section 2.1) and to determine the parameters that are relevant to answer the question of the current degree of SAR integration in the AAL ecosystem (Section 2.2).

2.1. Article Selection Criteria

We carefully curated a collection of papers on the topics of the use of SAR as an element within an AAL ecosystem. Our selection process involved a thorough review of the literature, drawing from the works of Abdi et al. [9], Trainum et al. [14] and Luperto et al. [15], and extended with additional and more focused citations on our specific topic. Thus, we selected the most relevant papers that explored the areas of SARs and AAL. These papers were further narrowed down by evaluating the quality and relevance of the references cited in each article. Finally, we prioritized the papers that were most frequently cited in previous works.

To obtain an idea of the number of articles published on our topics of interest, we can refer to the graphs in Figure 1. These graphs were generated using data from the Web of Science [16], and show the following results:

- For the theme TS = Ambient Assistive Living NOT TS = robot, we obtain 2833 results in the range 2009 to 2023. The graph shows a relatively steep upward slope until 2015 and a gentle downward slope thereafter. It seems to imply that the issue created a significant expectation and that we are now at the point where realistic deployments are expected.

- The topic TS = Assistive Robot AND TS = social NOT TS = Ambient Assistive Living has its most relevant point in 2021, with a much lower interest than that generated by the previous topic, and with a clear reduction in these last two years.
- Both topics, especially the former, far exceed the interest in the topic TS = Ambient Assistive Living AND TS = Assistive Robot. Only a total of 68 articles were published in the period between 2009 and 2023.

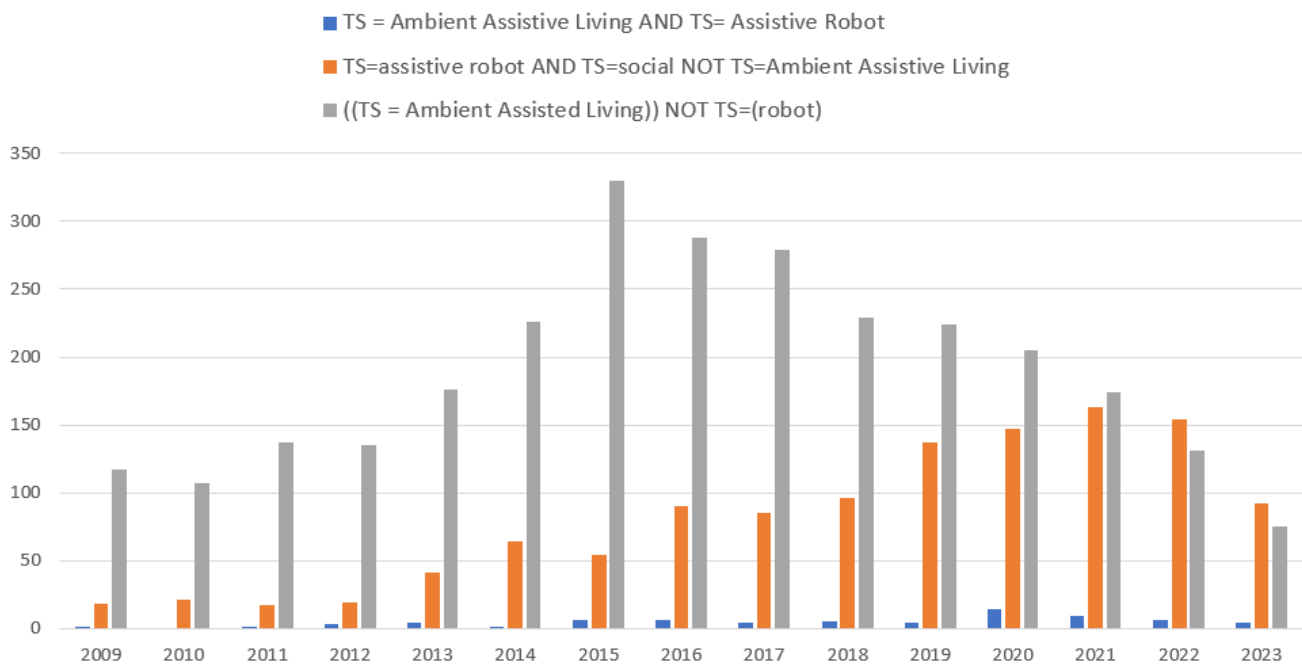


Figure 1. Web of Science Analyze filter.

2.2. Relevant Parameters for the Study

Possibly the most important aspect to assess in terms of understanding the importance of the deployment of robotic technologies in AAL ecosystems is the tasks or services (use cases) that the robot can address to help the elderly. For instance, the Government of Japan identified several areas in nursing care that can require the introduction of robotics (lifting and mobility aids, toilets, monitoring and communication systems, bathing... [17]). In the specific case of SARs deployed in nursing homes, Broadbent et al. [18], according to the opinions of residents, relatives, and workers, identify several tasks suitable for such robots: automatic fall detection, monitoring of people's location, monitoring of activity and vital signs, and communication and reminders of activities and tasks, such as taking medication. This contribution highlights the fact that a social robot can execute all these tasks automatically and proactively by searching for the user, proposing tasks, or initiating interactions. This can be a determining advantage for the use of SARs in nursing homes [12,19]. The importance of this parameter has made it one of the basic axes to be analyzed in this study. The other two important axes are the type of robotic platforms used in this scenario and the duration of the experiments carried out. Before starting the analysis, it is important to stress that SAR experiments have traditionally been affected by short duration, biased selection of participants, and incorrect experimental procedures [4,20]. This review aims to compare objectively the different contributions. Only well-documented, rigorously curated papers are considered. Moreover, the particular context, objectives, and methods of the analyzed papers are often detailed in the survey in order to minimize the effects of previous issues on the provided conclusions.

3. The Use of SAR in AAL Ecosystems

When analyzing contributions on SAR, Abdi et al. [9] distinguish between service robots, which aim to assist users in their daily activities, and companion robots, such as the one described by Wada et al. [21], which aim at the psychological well-being of the people they accompany. Focusing on the first category, service robots, it can be concluded that they currently have two main drawbacks:

1. They usually offer very simple functionalities, mainly associated with supervision, with a gap between these functionalities and those required by end users, which would require the design of more complex but equally robust robot performance planning and control schemes.
2. The deployment of these robots in a real intelligent environment requires the maintenance of a unique representation that brings benefits to both the robot and the environment. This is still in its early stages, with few projects showing evaluations obtained from actual long-term deployment [22].

Several recent works address these two drawbacks. Hence, to enhance the capabilities of the robots themselves and enable the creation of more general service robots, the integration of these robots with AAL environments has been proposed [23,24]. For example, the GiraffPlus project [25] deployed a teleoperated mobile robot in an elderly person's home, equipped with a network of sensors, to monitor the user's daily activities. In this project, however, the robot is semi-autonomous, i.e., it is controlled by an external user to navigate the elderly person's home when necessary, and the system only facilitates navigation. The integration of autonomous robots with AAL platforms is studied in [26–28] with robots whose main purpose is to identify possible falls. Their integration with a larger AAL architecture would offer additional services such as reminders, picking up and placing objects, and suggestions for entertainment activities.

However, only a few studies have deployed SAR in real environments. A relevant example is Strands [29], in which an autonomous social robot was deployed in the common areas of a residence hall. In this case, the robot was deployed in large-scale environments to simultaneously assist multiple users (e.g., by giving them directions). This context poses different challenges than those evaluated in the MoveCare, CompanionAble, or SERROGA projects [30,31], where the goal was to provide assistance to a single user in their own home. More recently, the SYMPARTNER project [32] showed the results obtained in a 20-week field study with 20 elderly people (one week per participant where the system was available to the user for five days).

Similarly, the EnrichMe project [33] evaluated the feasibility of long-term deployments within the home of 10 elderly people for 10 weeks. The main objective of this project was to provide everyday tools and applications to assist the elderly at home. These tools focused on monitoring (body temperature, heart rate, and breathing), complementary care (diet and medication reminders, physical and cognitive exercises), and daily support (phone calls, finding objects, weather, and news providers). Although the EnrichMe project is similar to the MoveCare one [15] in their platform and deployment, they differ in their approach and, thus, in the type of scenarios they support. The EnrichMe project focused on assisting elderly people in their daily tasks, while MoveCare focused on monitoring early mild cognitive impairment and stimulating users.

An example of a significant deployment is the one promoted by the local governments in South Korea. A total of approximately 7000 Hyodol robots have been deployed in the homes of elderly people living alone [34]. The aim is to provide help and companionship. The latter aspect is much more prevalent in Asian countries, where the robot is more readily accepted as a companion than in Europe or the United States [17].

Similarly, an additional example is led by the Spanish company Grupo Saltó [35]. Together with the Barcelona City Council, the company is leading the deployment of a social robot at home to assist elderly people to live independently at home. In the first phase, from February 2020 to February 2021, the ARI robot (a Misty-II, see Figure 2) was

deployed in 10 homes, to assist people over 65 years of age and with a good degree of mental and physical autonomy, who live alone at home. These users are assisted by one of the four robots used in the pilot for a period of 2 months. The objectives are to reduce the loneliness of the person, as well as to monitor their state of health and prevent them from forgetting to take their medication. In a second phase (lasting 3 years), the pilot will be extended to 100 homes, and the robot will be replaced by a Temi (Figure 2 (Right)).



Figure 2. (Left) Misty-II robot, and (right) Temi robot. Source: Misty Robotics and Temi, 2024.

Another example of significant deployment is the “Living at Home” project [36], which aims to enable people in a situation of dependency to live independently and with dignity in their own homes, without having to live in a nursing home with the help of social services and technology. The pilot of this project involves 15 dependent people, each with their own needs. In each of the homes of these 15 participants, a home automation system is installed, equipped with sensors and other devices capable of monitoring all the routines within the home and guaranteeing the safety of the person living in the home. In addition, a SAR, in this case a Temi robot, is also installed in the houses. Although there are only 3 robots deployed so far, the aim of the project is to install Temi robots in the other 12 houses.

3.1. Robotic Platforms

When analyzing the publications on the subject, the first of the points that can be highlighted is the diversity of robotic platforms used. Table 1 summarizes some examples, clustered into three main groups. One group includes platforms that are small in height and whose main advantage is their ability to display either facial or gestural emotions. One example is the previously mentioned Misty-II robot (Figure 2 (Left)). Other examples are the popular Nao [37–39] or LuxAI’s QTRobot [40–42]. Figure 3 shows the external aspect of these two platforms. Aldebaran Robotics’ Pepper robot was used by Bui et al. [43] and Bui and Chong [44]. This robot has a higher motor capacity, which allows it to move around the environment, and a larger size, which facilitates face-to-face interaction with the user. In general, they are emotional robots designed primarily to interact with people. They present hardware limitations when it comes to performing other tasks. For instance, it is common to deploy an external camera to increase the sensory capabilities of the Nao robot [39].

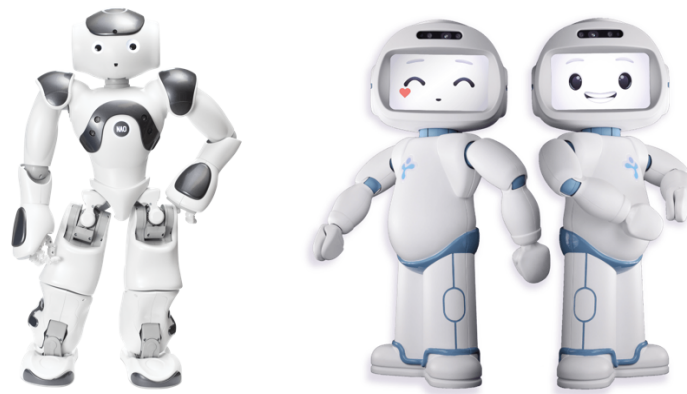


Figure 3. (Left) Aldebaran's Nao robot, and (right) LuxAI's QTRobot. Source: Aldebaran and LuxAI, 2024.

Table 1. Examples of robotic platforms identified in the survey.

Type of Robot	Examples	Relevant Features
Humanoid robots	Misty-II Nao QTRobot Pepper Hyodol	Emotional robots, designed for HRI
Autonomous Mobile Platforms	Robotnik RB-1 Kompai-2 robot Morphia TIAGo Giraffe-X Temi Care-o-Bot	Objects manipulation Designed for HRI Social navigation Objects manipulation Telepresence robot Social navigation Objects manipulation
Customized Platforms	iAirBot TurtleBot Robotic wheeled walker Rolland	Indoor air quality monitoring Intuitive user-machine interface Help people to move in crowded scenarios Smart wheel-chair robot

Mobile platforms are more popular. In Barber et al. [45]'s proposal, two robots are used to provide different services. One of them is a user-friendly robot built on a TurtleBot2 base. Its mission is to provide companionship to the elderly person, so it is designed to interact. The second, a Robotnik model RB-1 (Figure 4 (Left)), is larger, has arms and end-effectors (up to 13 degrees of freedom), and can perform household tasks. Although it is not very common to find robots deployed in these scenarios with the ability to manipulate, there are notable exceptions, such as PAL Robotics' TIAGo [46] or the Care-o-Bot [47]. In the ALMI project, the robot uses this ability to manipulate objects to assist a person with mild motor and cognitive impairments. Ayari et al. [48] describe two scenarios dedicated to the assistance of a frail person in a smart home equipped with a Kompai robot and smart objects (Figure 4 (Right)). This robot was also chosen by Zsiga et al. [49] in the Domeo project, funded by the Ambient Assisted Living Joint Program of the European Union. In the MoveCare system [15], the Giraffe-X robot is deployed. The HOBbit robot [50] provides autonomous navigation, a manipulator with a gripper, and a multi-modal user interface allowing interaction via speech, gesture, and touch screen. In the joint research project MORPHIA (Mobile Robotic Care Assistant to Improve Participation, Care, and Safety in Home Care through Video-based Relatives Network) [51], several platforms have

been developed [52]. Figure 5 shows the last version of the Morphia robot, developed by the company MetraLabs GmbH Neue Technologien und Systeme Ilmenau.

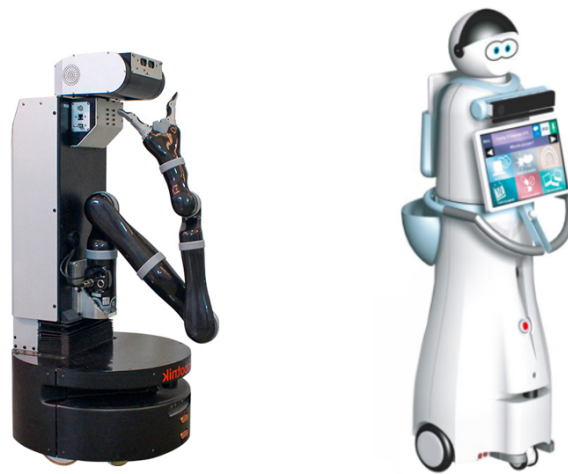


Figure 4. (Left) Robotnik RB-1, and (right) Kompai-2 robot. Source: Robotnik and Kompai Robotics, 2024.



Figure 5. The Morphia robot from MetraLabs GmbH.

As mentioned above, the design of the robot is closely linked to the tasks to be performed. This aspect is particularly relevant in some proposals, where a customized design for the robot is proposed to fit these specific tasks. For example, the iAirBot robot is an assistance robot for indoor air quality monitoring built on top of the TurtleBot2 robot [53]. It is equipped with a Kinect camera to scan, locate, and track people in indoor environments and an iAirNode gateway. This gateway allows the robot to receive data from a network of indoor air quality measurement sensors. Spournias et al. [54] also employs a TurtleBot2 for building a robot that can detect the status of a door. When a route includes crossing a closed door, the robot sends a signal to the door mechanism to open it. A Turtlebot was also deployed in the proposal by Linner et al. [55]. In this case, the robot is employed as an interface between the user and the environment (the robotic micro-rooms, RmRs). Moreover, the robot can help users when they carry shopping bags or baskets, as it can transport them within the rooms. Anastasiou [56] described the use of an intelligent wheelchair-robot (Rolland) in the Bremen Ambient Assisted Living Lab (BAALL). Nazemzadeh et al. [57] deployed a robotic wheeled walker, which is endowed with a multisensor data fusion approach. The goal is to help people with motor or cognitive impairments to move in large and crowded environments.

3.2. Expected Services

The robot deployed in an AAL can assume the role of being the interface to the rest of the system. For instance, this is the case in the proposal by Bui and Chong [44], where the user communicates with the robot to access and control devices/information appliances in the smart home. Similar use cases are identified in [40–42]. But there are, of course, many other roles or functionalities that such robots can take on.

In general, to identify what services people expect from service robots, previous work used interviews that were conducted by asking a series of questions to the people involved, often after a controlled demonstration, to show examples of the robot's capabilities [58,59]. Other work conducted focus group interviews, directly asking potential users to describe the functionality that could be expected from these platforms [60–62]. This second approach also included demonstrations, usually with limited autonomy [63,64]. In the end, only a limited set of these identified functionalities have been implemented in SARs. In the aforementioned MORPHIA project [51], the robot is used for closing the communication gap between users and caregivers. Thus, elderly people can use the robot to communicate via video or chat with relatives, friends, or caregivers. The robot can remind users to take medication or to transport meals or personal items within the home (as the Turtlebot robot deployed in the RmR AAL ecosystem [55]). When an incoming call comes in, the robot can look for the user. Relatives living far away can use an intelligent remote control to keep an eye on things in the home or support them in certain activities via telepresence. In other proposals, the robot acts as a virtual therapist, which proposes the user physical or cognitive activities [15,40–42,65]. Similarly, the robot can stimulate the user it accompanies to perform everyday activities [66]. Other functionalities are fall detection [67], meal assistance [68], or information and stimulation through messaging. In the aforementioned ALMI project, the TIAGo robot uses both its speech interaction for voice instructions and its object manipulation capabilities to help a user with mild motor and cognitive impairments prepare a meal. Speech interaction is also the main functionality deployed by the robot in the proposal by Gulzar et al. [69]. In the RiSH proposal [70], human body activity recognition is addressed using inertial measurement units (IMU) and a home service robot that perceives the environment through audio signals. The applications that are provided are human position tracking and human activity monitoring. The recognition of activities, normal or abnormal, is also the service provided by the AAL environment and the robot in Mojarad et al. [71]'s work. The proposed framework includes long-term memory models (LSTM) as well as reasoning based on Probabilistic Answer Set Programming (PASP).

The different services offered often involve monitoring certain variables. Sometimes, the parameters monitored are related to activity recognition. This is, for example, the case in the proposals by Do et al. [70] or Mojarad et al. [71]. Daily activities carried out are also monitored in the proposals by Coradeschi et al. [25] or in the Living at Home project [36]. The monitoring of falls, either their possible prediction or their detection, is present in numerous studies [26–28,67]. In the EnrichMe project, body temperature, heart rate, and breathing are monitored [33]. Similar parameters are evaluated to determine the state of health in the solution provided by the Saltó group [35]. The early mild cognitive impairment is analyzed in the MoveCare project [15]. Finally, less emphasis is placed on the monitoring of environmental parameters (e.g., indoor air quality [53]).

3.3. Temporal Duration of Deployments

Table 2 summarizes some of the main characteristics of the studies presented in a set of papers identified in Figure 1 and published between 2009 and 2023. For some of these papers, the duration of the experiments was not clearly stated in the publication but was available from press releases or the websites of the companies or academic institutions involved. In these cases, the data are reported as significant but are not included in the table.

Table 2. Summary of studies in the topic TS = Ambient Assistive Living AND TS = Assistive Robot between 2009 and 2023 involving real users.

Study	Year	Implication	Number of Users	Duration
[15]	2023	deploy at home, unattended	25	10 weeks
[72]	2023	experiments at nursing institution	10	2 days
[73]	2022	survey	197	
[45]	2022	capture data from bracelet	2	47/114 days
[74]	2021	capture data from bracelet	4	15 days
[66]	2020	deploy at home, unattended	20	5 days
[75]	2019	survey	188	
[38]	2017	demonstration and survey	18	
[48]	2016	experiments at home	1	
[55]	2015	experiments in laboratory	6	1 session
[37]	2013	experiments at senior citizen homes	16	2 sessions
[49]	2013	focus group	32	1 session
[56]	2012	capture data in a controlled environment	20 (young)	20 min

Unfortunately, many of the deployments are of very short duration (a few days or even a few sessions). But there are significant exceptions. For example, Luperto et al. [15]’s article documents the tests carried out as part of the MoveCare project. The aim of the project is to develop and field test an ecosystem to support the independent living of the elderly at home by monitoring, assisting, and providing social, cognitive, and physical stimulation. In the experimental testing, 25 elders participated. The whole system was installed in the apartments of elders living alone and used for 10 weeks each. As aforementioned, the EnrichMe project evaluated the feasibility of long-term deployments [33,76]. The EnrichMe ecosystem consists of a robot, a number of environmental and movement sensors, and a networked care software platform. It was tested in two settings: in two Ambient Assisted Living (AAL) laboratories (Fondazione Don Carlo Gnocchi, in Italy, and Stichting Smart Homes in the Netherlands) and three elderly care housing facilities (Lace Housing Ltd LACE, in the United Kingdom, Osrodek Pomocy Społecznej- PUMS, in Poland, and Aktios Licenced Elderly Care Units, AKTIOS, in Greece). During the first evaluation in Italy, which involved four elderly people with mild cognitive impairment (MCI) and six caregivers, a Kompaii 2 robot was used. For the rest of the evaluations, a TIAGo robot without arms was deployed. For the last evaluation, the ecosystem was tested in the elderly case housing facilities (i.e., LACE, PUMS, and AKTIOS). On each site, two robotic systems were deployed. A total of 11 participants (4 males and 7 females) participated in the testing. The testing duration for each participant ranged between 7 and 10 weeks. The ages of the participants range between 70 years old and 90 years old [77].

From 15 November 2021 to 21 July 2022 (with a lockdown period due to COVID-19 from December 2021 to March 2022), the CLARA robot was deployed in the Vitalia Teatinos nursing home (Malaga, Spain) [78] (see Figure 6). Although the experimental validation focused more on the robot than on the AAL environment in which it is embedded, the idea is that the robot shares a representation of the environment with this ecosystem so that sensors deployed in the environment augment the robot’s capabilities and the robot can update information about the environment through its ability to navigate autonomously. Nine residents, aged between 65 and 85, actively participated in the validation tests.



Figure 6. The CLARA and Gobe robots in the Vitalia Teatinos nursing home.

4. Discussion

Despite the wide variety of services provided by AAL systems and their undoubted potential, the truth is that their efficacy and acceptance have not yet been robustly demonstrated. We can assume that, in part, this is due to the assumption of a utopian vision of gerontotechnology, which assumes that the mere application of technology brings positive results. The truth is that good adherence is not achieved with just any technology introduced to assist older people. In fact, the most common type of sensor is the one that coincides with the most demanded by workers and end users: sensors for fall detection. Even this type of sensor can encounter difficulties in being fully integrated into the daily lives of residents: Broadbent et al. [18] report an adherence of only 20% to these technologies in the homes evaluated. Hall et al. [8] obtain similar data. The reasons that hinder this integration of AAL technologies are diverse. The main problem, as mentioned in Section 1, is that systems have been designed and implemented without taking into account the opinions, requirements, preferences, and reluctance of all system stakeholders in the process [8,18,79]. Ethical considerations also need to be kept in mind regarding privacy, but also the use of systems that can potentially and paradoxically reduce human contact and personal freedom of the user [80]. Ultimately, it must be borne in mind that technology must adapt to the user, not the other way around [8]. Moreover, users should not only be involved in the design process. They will also have to be consulted and involved in the concrete choice of technologies to be implemented [79,81]. Again, with special consideration to criteria of acceptability, privacy, and usability. Finally, once the technologies have been chosen, it will be necessary to fully train workers in their use in order to establish automatisms and discard inefficient operations [8].

In the field of SAR, it is commonly claimed as an advantage that people are more predisposed to act, change their behavior, and learn in the presence of other people, but also in the presence of embodyable agents, such as a social robot [82]. In this sense, such agents provide a more entertaining and motivating context than, for example, a mere screen. While this hypothesis has been shown to be true, it is worth particularizing in this case for SARs that function in care homes for the elderly. According to the results of Broadbent et al. [18], shared by other studies [9,83], for end users, caregivers, and healthcare professionals alike, functionality is the key to acceptance for these robots. Indeed, there is a preference for a robot that looks like a machine that is activated only when it is to be used and that is always perceived as a tool, not as a substitute for a person.

Regarding their limitations, as with AAL technologies, SAR is relatively recent and therefore suffers from the same problems: lack of long-term acceptability and utility studies, lack of reproducible experiments, lack of consensus, and, often, lack of rigor in

experimentation. It is also common to find proposals that have not been designed with the user's needs and preferences in mind. Such proposals, systematically, often encounter many problems in their implementation. Abdi et al. [9] conducted a review which shows that the potential for the use of SARs is very high, but the studies and works that use them have, to date, frequent methodological flaws. This study highlights that the great advantage of SARs is not so much that they can execute tasks by assuming a certain role but that they can be adapted to assume different roles, performing different tasks with the same platform and the same interfaces.

The area of application where SARs perform best is when they take on the role of social facilitator. In interactions where the SAR interacts with a group of users, all the studies conducted show an appreciable improvement in people's sociability and record positive opinions about the robot. It can be said that the robot offers a common nexus on which to build social interactions. With this in mind, it is in the context of a nursing home that social assistive robots may be most useful. In contrast, the use of SARs in the home is much less effective, and the current cost of a SAR (although it has fallen significantly in recent years) may justify its use in a nursing home, but less so in a private home.

The following considerations should be added to these conclusions: first, a SAR will see its functionality increased if it is integrated into an AAL ecosystem [4,12]. Second, the use of an assistive robot, as well as the aforementioned assistive technologies, should never replace human interaction and contact between residents and healthcare staff or their relatives [80]. Finally, the use of SAR and AAL in nursing homes should always be seen to improve the quality and increase the services offered to residents, and never as a mere means to reduce costs [18].

5. Conclusions and Future Work

This survey analyzes the deployment of SAR in AAL ecosystems to assist the elderly. During recent years, the integration of SARs in AAL ecosystems has proven useful for monitoring and assisting older people. However, the difficulties associated with their long-term deployment in a real-life environment still need to be studied in depth. The analysis of recent studies highlights the advancements in this specific field, emphasizing the need for the design of these solutions to take into account the needs and preferences of the end users, both those who will have to share their daily lives with the technologies implemented and the carers or professionals who look after this population. When this co-design process is not approached seriously, doubts arise. It is not only that human contact is preferred, which is considered irreplaceable in most studies, but even in Japan, where people are much more familiar with the presence of robots and where a policy of including new technologies for care has been in place for almost years, care professionals are still very hesitant about assistive technologies in general [3,84].

Future work in this field should focus on thoroughly reviewing existing experiments and exploring ways to further improve robot acceptance. The largest experiments that have been conducted to date, mainly in Japan or South Korea, show that the perceived ethical or social implications of these new technologies, as captured by interviews with end users, caregivers, and medical professionals [81,84], are mainly linked to factors related to acceptance, privacy protection or the use of personal information, and the relationship between perceived benefits and risks. In the studies conducted, the willingness to use these technologies for the care of an older person is considered high due to the perceived benefit of the services offered and the appropriate use that is usually made of personal information. Given that these two factors seem to be correctly perceived, in general, new work should take into account that, in order to improve the willingness to use these new care technologies, it will be necessary to increase efforts to promote and improve acceptability and privacy protection. Briefly, as aforementioned, users should be involved in the design procedure and in the concrete choice of technologies to be deployed.

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