Archives of Gerontology and Geriatrics Plus 1 (2024) 100056

Contents lists available at ScienceDirect

Archives of Gerontology and Geriatrics Plus

journal homepage: www.sciencedirect.com/journal/archives-of-gerontology-and-geriatrics-plus

New technologies and assistive robotics for elderly: A review on psychological variables

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ARTICLE INFO

Keywords:
Elderly
Intelligent assistive technologies
Ambient assisted living
Social assistive robotics
Acceptability

ABSTRACT

The article reviews recent research on new technologies for assisting the elderly based on Artificial Intelligence: Utilities for smart houses and Ambient Assisted Living, wearable and monitoring devices, virtual and augmented reality, and assistive robotics.

These smart technological tools can reduce the isolation of older adults by assisting them in their daily activities, but without completely replacing direct interventions, and requiring human support to facilitate interaction.

In determining the effectiveness of assistive technologies, older people's perceptions of them, acceptability, and willingness to use them are key variables. Also relevant is the perception by caregivers and healthcare professionals, and the socio-cultural dimension of acceptability.

Finally, the paper presents the ethical issues related to the use of technologies with the elderly population, to ensure the autonomy, safety, and dignity of the person. Some suggestions are offered for developers of new technologies for older adults.

In conclusion, the challenges for the future of assistive technologies are highlighted, so that they can best be used to assist large and differentiated elderly populations.

1. Introduction

The increase in the longevity of the population and the conditions of socioeconomic well-being have led to a growing need for assistance for elderly people - vulnerable and not - partly satisfied through the development of technologies based on Artificial Intelligence (AI).

Innovative ways of assisting the elderly are being developed based on mobile digital technology, i.e. through hardware devices, such as PCs, tablets and smartphones, and special software designed for specific target populations. Also, very widespread technologies are those based on virtual reality and "social robots", designed to help the elderly with daily activities. These technological innovations are useful in providing physical and psychological assistance to the elderly, thus improving their quality of life.

The label *Digital Healthcare and Digital Therapy* (DTx) indicates the appropriate tools to allow patients and fragile subjects to acquire suitable coping strategies to achieve the best level of quality of life, providing for an active role of both the user and the caregivers who assist them. Among these tools, Sapci and Sapci (2019) listed:

- apps for Smart Houses and sensor-based systems, for elderly people who live alone;
- robots for home care and telemedicine apps, for elderly people who live with family members;
- wearable and remote monitoring devices, for elderly people living in residential communities;
- assistive technologies for elderly people with dementia living in nursing homes and assisted living facilities.

According to Abdi et al. (2021), greater scientific support emerges on AI-based apps, voice-activated devices, and portable diagnostics. There is partial agreement for wearable devices, Internet of Things (IoT)-enabled homes, self-driving vehicles, and autonomous assistive robots; virtual reality, augmented reality, mixed reality, exoskeletons, and new drug delivery mechanisms gain less consensus.

Hamid et al. (2023) have identified several macro categories (robotics, virtual reality, smart textiles and wearable devices, centralized health information systems), which promote physical-cognitive activities, social interaction, emotional-affective support and health

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https://doi.org/10.1016/j.aggp.2024.100056
Received 23 April 2024; Received in revised form 9 June 2024; Accepted 16 June 2024
Available online 25 June 2024

management and monitoring, positively influencing a healthy lifestyle.

The narrative review will examine in detail the types of assistance and the related studies, regarding populations of elderly people without pathologies or mental deterioration, and limiting the review to the studies of the most recent years, although citing some previous pivotal research.

The review structure is structured as follows: after a global consideration of the technological assistance to the elderly and of the models used to implement it, e.g. for the Smart Homes and Ambient Assisted Living (AAL), virtual reality and social robotics will be addressed separately. Then we will deal with the perceptions and expectations influencing the acceptability, and the social and cultural aspects involved. Specific paragraphs will be dedicated to the critical issues emerging from the reviewed literature, the ethical aspects, and the role of the developers of new technologies for the elderly.

2. Technological assistance to elderly

In recent decades there has been growing attention towards the use of mobile digital technologies, which offer tele-assistance and support to elderly people in daily life and health management, thanks to advanced artificial intelligence and Information and Communication Technologies (ICT). These technologies enable disease diagnosis, medication management, physical activity monitoring, fall detection, and emergency calls, while also helping to prevent loneliness (Weck & Afanassieva, 2023).

A large multicentric project, funded by the European Horizon2020 Programme, has developed and tested the *MoveCare* platform (*Multiple-actors Virtual Empathic Caregiver for the Elder*: www.movecare-project.eu) aimed at assisting the elderly through the integration of intelligent devices, home automation sensors, virtual reality, and a virtual caregiver, including a robotic one. The system, thanks to a modular design, can be tailored to achieve, for each elder, ecological monitoring of frailty, through measurements recorded during common daily-life activities, providing caregivers with current information on the elder person's status (Lunardini et al., 2019).

Thakur and Han's (2021) review explored the relationship between older adults and daily activities referring to the "Activity Theory". Two approaches to monitoring Activities of Daily Living (ADL) have been identified: recognition based on wearable and wireless sensors and that based on cameras and artificial vision techniques. The review also highlighted future challenges regarding data security, trust in technologies, and the social inclusion that can be achieved through them.

A review of the literature on the autonomization of the elderly through Assistive Technologies (AT) confirmed their effectiveness in various domains, such as mobility, personal management of the disease, taking medications, hearing and vision, highlighting the effectiveness of apps for the personal management of health conditions (Fotteler et al., 2022).

Al-Saleh et al. (2024) proposed a digital therapeutic self-management system called *MEDSReM©* aimed at improving adherence to hypertensive medications. The study demonstrated a significant increase from 72.5 % to 91.0 % in treatment adherence using this system.

Furthermore, the problem of falls in the elderly has been addressed through the development of smartphone apps based on accelerometers useful for detecting them (Stampfler et al., 2022).

To evaluate the acceptability of new health technologies, models such as the *Health Belief Model*

(HBM) and the *Technology Acceptance Model* (TAM) have been used.

The study by Richardson et al. (2022) revealed that past experiences influence the acceptability of new technologies, especially for patients with limited accessibility to technological tools. The acceptance of the use of artificial intelligence by healthcare professionals was examined through the SHAIP Questionnaire, highlighting a generally positive view towards the technology. However, Shinners et al. (2022) underlined the need for targeted trainings for specific needs.

The evolution of the *Smart Home*, integrated with technologies based on Artificial Intelligence, has led to improvements in healthcare, environmental, financial, and psychological advantages linked to well-being and social inclusion. These devices offer services such as monitoring, counseling and therapeutic assistance, improving accessibility to care and reducing medical errors. In the long term, they contribute to promoting the well-being of older people, environmental sustainability, and accessibility of healthcare, overcoming the feeling of isolation (Marikyan et al., 2019).

Several studies have highlighted the importance of *Smart Home* and *Ambient Assisted Living* (AAL) in supporting independence and counteracting social isolation among older people. In particular, a research conducted by Fritz et al. (2020) demonstrated that the Smart Home can detect and manage chronic pain, recognizing pain-related behaviors and offering support for both the recipient and informal and formal caregivers. Furthermore, thanks to advanced systems such as fall detection, AI-based home appliance control, assistive devices, and personalized spaces, the Smart Home helps prevent domestic accidents and the risk of accidents, contributing to maintaining the independence of older adults (Gawrońska & Lorkowski, 2021).

A crucial aspect of Smart Home systems is the monitoring technique, which is more effective when equipped with visual and audio sensors. Smart speakers, as demonstrated by Kim et al. (2021), have been successfully used to enhance cognitive functions, preventing cognitive decline through programs such as *Metamemory training* (MMT).

According to the review by Momin et al. (2022), the integration of Artificial Intelligence (AI) and *Computer Vision* (CV) techniques, with less privacy-invasive approaches, such as transfer learning and deep learning, allows recognition of critical situations such as falls or breathing problems. These advanced systems can promptly alert family members and rescue officials, thereby improving the safety and well-being of elderly people living in Smart Homes.

Burzagli et al. (2021) highlighted the importance of designing AAL to improve the well-being and quality of life of older adults. The approach focused on maintaining autonomy in carrying out daily activities should be based on knowledge of the specific needs of the people concerned. AAL technologies should be able to monitor and adapt the support provided, respecting people's ethical values and promoting social contact. However, there is still a lack of awareness among older people about how new technologies can improve their autonomy at home (Street et al., 2022). Many older adults show a reluctance to use technological devices; while others accept them on the condition that the technologies augment human assistance rather than replace it.

The review by Liao et al. (2023) highlighted an increase in studies on Smart Homes for older adults in recent years, with dominant themes related to healthcare, energy management, and home automation. The need to simplify the use of AI technologies for older adults and to increase control over sensitive data to ensure safety is highlighted. The authors also suggest an increase in multidisciplinary research that includes humanistic and sociological aspects of engineering and intelligent technologies.

In general, preliminary evidence for the role of Smart Home technology in supporting older people's quality of life was demonstrated, particularly for those who live alone, fostering the sense of aging independently and securely in their own homes (Aggar et al., 2023).

Finally, the study by Hartmann et al. (2023) concludes that the implementation of AAL technologies, equipped with artificial intelligence, has improved the quality of life of the elderly, but there are still challenges, such as privacy policies, data security protocols, and digital literacy of users, to overcome the current limits of these technologies.

3. Virtual reality

Virtual reality (VR) and augmented reality (AR) are innovative technologies that are gaining popularity in healthcare, including for the elderly.

A review conducted by Marston and Samuels (2019) highlighted the usefulness of personal or virtual assistance, the integration of virtual assistants and apps, and exergames to improve the quality of life of the elderly. Syed-Abdul et al. (2019) confirmed the acceptance of VR among older adults, showing that it is perceived as useful, easy to use and fun. The perception of usefulness, pleasantness, and ease of use influence the intention to use VR.

To respond to the increasing need for assistance for elderly people lacking family support, new solutions are being explored. An example is the *Assistive VR Gym*, an experimental project (Erickson et al., 2020) that uses a virtual gym to allow people to interact with virtual robots. These interactions help improve the effectiveness of robots and bridge the gap between physical simulations and real-world activities.

Ghorbani et al. (2022) report preliminary results on an intelligent assistive system integrating augmented reality and serious games for adaptive decision-making. The responses given in semi- automated mode were better compared with the fully automated mode.

A review dedicated to Virtual Reality specifically used to assist elderly people with cognitive impairment was presented by Costanzo et al. (2023).

Virtual Reality is also proposed as a valuable tool to counteract social isolation by offering the elderly engaging social experiences and promoting socialization. Virtual cycling experiences, as in the study by De'Sperati et al. (2023), were very well received by the elderly participants, suggesting that VR can be a positive and engaging experience even for the so-called 'oldest old' population (80 years or older); moreover, the high overall user experience index obtained, and the minimal levels of cyber-sickness confirm a high acceptance.

Immersive VR can also help the elderly manage anxiety. Rmadi et al. (2023) demonstrate a reduction in anxiety in the majority of participants, without causing significant side effects, except for some mild symptoms of cyber-sickness; thus, immersive VR is well tolerated by elderly residents in care homes.

Some benefits of VR are the promotion of physical activity and the consequent increase in psychophysical well-being; through immersive and engaging experiences, it promotes physical activity in the elderly, counteracting the negative effects of sedentariness and improving their general well-being. Gabbi et al. (2024) confirm the validity of using mixed reality (MR), such as *Microsoft HoloLens*, highlighting an appreciation by the elderly for the physical, cognitive, and psychological benefits of these technologies.

Immersive VR proves to be a promising approach to improving cognitive functions, especially memory, and the psychological well-being of the elderly. For instance, reminiscence therapy using VR stimulates memory and enhances neural connections in the brain, promoting the consolidation of memories and improving cognitive abilities, showing superior effectiveness compared to traditional therapy (Abd El Fatah et al., 2024).

Augmented Reality facilitates the use of technological devices by the elderly, promoting their digital inclusion and consequently improving their quality of life. Jin et al. (2024) emphasize the promising potential of AR in this regard, but point out the need for careful and inclusive application design; in detail, factors related to ease of use, accessibility, and psychological comfort need to be addressed to ensure the success of AR in elderly care.

The enjoyment of VR and AR can be influenced by factors such as familiarity with the technology and the psychomotor abilities of the elderly. Bradwell et al. (2024) highlight the need for appropriate user training and user-friendly design to ensure a positive experience. The study demonstrated the technological feasibility of using omnidirectional VR treadmills and static VR experiences, such as *Motus VR*, to promote physical activity and well-being in the elderly; however, a significant barrier emerged regarding independent use by users due to a lack of confidence in using the technology without researcher supervision, suggesting the need for more in-depth training for future users.

Another aspect to consider is the emotional impact of virtual tools. The immersive VR can arouse intense emotions in users, especially in the elderly who might relive both beautiful and pleasant memories and traumatic events. Ramalho et al. (2024), in this regard, note that the over-emphasis on virtual technology may lead to a disconnection from reality and authentic human relationships. In particular, attention should be paid to several points such as familiarity with the technology, design, and content (realistic, engaging and age-appropriate), and psychological impact, as VR may awaken memories and deep emotions that are not always positive.

In summary, virtual or augmented reality offers promising opportunities to improve the lives of older adults by providing support in daily activities, enhancing the quality of life, and providing assistance when family support is limited. However, the reliability of these technologies should be increased (Abdi et al., 2021). Collaboration between researchers, developers, and healthcare professionals is crucial to designing and implementing effective, ethically sound, and accessible VR and AR solutions for all older adults.

4. Social robots to support the elderly

Socially Assistive Robotics (SAR) offers support to the elderly both at home and in care facilities, responding to the growing need for assistance in a society where few families can care for their elderly. Seniors want to maintain independence and live in their own homes, even when they need assistance. Technological innovations based on artificial intelligence, such as SAR, represent a useful solution, as they help the elderly carry out daily activities, such as getting out of bed, bathing, and taking medicine, allowing them to live independently. In addition, they promote regular exercise, improving physical fitness, sleep, the immune system and reducing the risk of diseases such as diabetes and dementia.

Several examples have long been present in concrete applications of robotics: *NICA* (*Natural Interaction with a Cares Agent*: De Carolis et al., 2009), and the *Multi-role Shadow Robotic System for Independent Living* (Pigini et al., 2012), were among the first projects for the development of a robotic system to ensure the autonomy of elderly people at home. The results were encouraging: the robotic systems proved capable of evaluating the specific context of the elderly person and adapting to it, relating to the elderly person, recognizing their emotional components and responding to them appropriately, remembering deadlines and tasks to perform, proposing cognitive exercises that stimulate attention and memory.

"Service" or "caregiver" robots such as *ROBOCARE* (Cesta et al., 2007) support the elderly's daily activities and allow independent living opportunities, together with robots similar to companion animals that contribute to improving psychological well-being, both at home and in residences for the elderly. They perform similar functions to pet therapy, but in better hygiene and safety conditions. The user interfaces are multimodal, and use technologies such as tablets, smartphones, web; some also allow telepresence interventions (Cesta et al., 2016).

A socially assistive robot system designed to engage elderly persons in physical exercise was presented by Fasola and Matarić (2013), demonstrating a clear preference by the users for the physically embodied robot coach, considered more attractive, enjoyable, and helpful than a virtual coach.

The project "Implementation and integration of advanced Robotic systems and intelligent Environments in Real scenarios for the Aging population" (ROBOT-ERA: www.robot-era.eu), tested robotic services designed specifically to assist the elderly at home, in condominiums or in external places, creating intelligent environments for cleaning services, waste disposal, shopping, organization of free time (Di Nuovo A. et al., 2014).

Romeo et al. (2018) underlined the need to implement an autonomous robotic agent able to adapt itself to older users, reading the level of engagement of the users at the initiation of the interaction, and autonomously learning how to respond in different situations.

Lotfi et al. (2018) conducted an experimental study that used a robotic assistance system to engage, motivate, instruct, and evaluate elderly people in motor activity via an app on an iPad connected to the *Double Robot*. The results showed a general satisfaction among the participants (with a greater participation of women than men), and a general increase in motivation to engage in physical exercise, enough to recommend it to others.

Advanced age also leads to an increased need for companionship, especially for those vulnerable to loneliness, in hospital or nursing home situations, as has occurred during the Covid-19 pandemic. The telepresence robots (*Giraff, TRIC, TELEROBOT*, and *Flo*), proposed by Reis et al. (2018), can satisfy these needs. These robots are mainly used in three areas: telemedicine, remote interactions with family and friends, and telematic health monitoring. Although the usefulness for both elderly people and operators has been demonstrated, important challenges remain to be faced, such as limited autonomy and respect for privacy, reported by users.

Huisman and Kort (2019) verified, through a longitudinal study, the effectiveness of the *Zora* robot in daily assistance and rehabilitation therapy, and healthcare facilities seem inclined to adopt it as a multifunctional assistant. Furthermore, *Zora* has been well accepted by the elderly, especially in psychogeriatric departments, as well as by people with disabilities and those who need support in cognitive, motor, and social activities.

McGinn et al. (2019) contributed to the development of robotic technologies for assisting the elderly in various situations by designing *Stevie*, a robot that, learning directly from operators in the field, facilitates their work and assists the elderly in retirement homes, hospitals, and at home.

By offering extensive use in nursing homes a low-cost virtual therapist who intervenes in case of emergency and facilitates communication with family members, the elderly's quality of life is improved and their psycho-physical decline is slowed down. However, it is necessary to improve the emotional aspect of the interaction, implement more accurate languages and responses, and promptly recognize abnormal physical reactions to act appropriately (Park et al., 2019). The *ENRICHME* project's *TIAGO Iron* robotic platform is also used to monitor health and offer social support, with the indication of using "soft robotics" to improve human-robot interactions, and make them more empathetic and customizable (Coşar et al., 2020).

The *HomeMate* robot (Lee & Naguib, 2020) is aimed at assisting the elderly by basing interventions on sociability and reliability. Interviews and focus groups with elderly people verified the validity of the scenarios, the presence of friendly avatars and the ease of learning gestures to facilitate interaction; however, greater safety in medicine delivery has been noted when handled by human operators. There is also a cultural influence, with preferences for quiet, non-invasive robotic behavior. Under these conditions, care robots and technological assistance systems, such as the *Tessa* robot, can become an integral part of the lives of the elderly, forming part of "well-being technology".

Robots can reduce the isolation of the elderly by becoming assistants in their daily activities. Carros et al. (2020) explored the effectiveness of using the *Pepper* mini-robot in a retirement home, noting its valid support for both cognitive and motor assistance; however, SAR cannot completely replace people and require human support to facilitate interaction. The usability of the mini-robot was confirmed by Salichs et al. (2020), highlighting its friendliness, safety, and intelligence perceived by users.

A study conducted in Norway (Søraa et al., 2021) interviewed a sample of older adults about "well- being technology," highlighting mixed opinions. However, a significant positive finding has emerged: access to these social robots can reduce loneliness, allowing elderly people to remain closer to their family members.

Another study conducted by Fan et al. (2021) employed the *SAR--Connect* integrated system that involves older adults in physical, cognitive, and social activities, integrating a humanoid robot with a virtual reality-based activity platform. The multimodal data acquisition including game interaction, audio, visual and EEG responses of the participants evidenced an improvement in the participants' performance, as well as confirming the usability and acceptability of older users.

In the field of assistive robotics, a prominent area is *Robotic Pet Therapy* (RPT), which uses animal-shaped robots such as the *Paro* robot, which has long been successfully tested with the elderly. A study conducted by Bradwell et al. (2022) examined the effectiveness of new cat-and-dog devices called *Joy for All* (JfA) within care homes. The results showed that interaction with JfA robots improved the well-being of the elderly, reducing psychiatric symptoms and promoting socialization.

Shen et al. (2022) presented the *Q-HARP* platform useful for assisting the physical mobility of the elderly, thanks to the support of a quadruped robot that offers stable support during walking. The results demonstrated the effectiveness of *Q-HARP* in basic performance and in simulating human movements, such as overcoming obstacles and difficult terrain.

Gasteiger et al. (2022) conducted a qualitative study on the effectiveness of the *Bomy* robot in caring for the elderly in nursing homes. The majority of participants accepted the robot, which was perceived as a companion or friend. However, technical problems and limitations in the type of games offered were reported.

The use of SAR in home contexts responds to the preference of elderly people to live in their own homes, where they find comfort and familiarity. The *GUARDIAN* system, presented by Margaritini et al. (2022), uses the *Misty II* robot and two connected apps to provide home care to the elderly, to improve autonomy, health, and quality of life, enabling them to remain in their own homes for as long as possible.

An important aspect of SAR in the elderly is the emotional component that the robot can manifest and decode in the user. Abdollahi et al. (2022) explored this aspect in depth by comparing the use of two versions of the *Ryan* robot: "empathic" (i.e., able to detect user's emotional states and to respond with an affective dialogue) and "non-empathic" (lacking facial expression and using only scripted dialogues). Both versions obtained overall positive effects, but the old persons perceived the "empathic" *Ryan* as more engaging and likable.

Halim et al. (2022) reviewed research conducted between 2000 and 2021 on the usability of SAR for older adults, identifying three key factors that interact to ensure its effectiveness: functionality, usability, and user experience. A critical element is the optimization of communication between the user and the assistive robot: the user should be able to communicate clearly and the robot should interpret adequately to respond appropriately. The user's physical characteristics (e.g., myopia) have to be considered from the moment of robot design, as well as the lack of technological experience among older adults. The review confirms that older adults prefer small SARs with a friendly animal-like design while reacting less positively to bigger anthropomorphic SARs.

Savage (2022), summarizing the studies conducted in various application sectors, talks about the "low rise" of assistive robotics, and the need for further studies to implement routine use both at home and in places of care.

Another review conducted by Sawik et al. (2023) evaluated the *M-CORAEUS* model for the efficient use of robots by elderly people, reducing caregivers' stress. The data obtained through focus groups allowed the emergence of some main categories that influence effectiveness (characteristics of the user, the robot, and its functions) but also concerns regarding the acceptance of robots.

Assistive robotics has found wide use in that area of transition between normal and pathological aging which is characterized by the symptoms of "Mild Cognitive Impairment": a recent review (Figliano et al., 2023) took stock of the positive effects even in this sector, underlining the importance of the intervention on the strengthening of social-cognitive skills for preventing dementia.

5. Perceptions and expectations influencing the acceptability of SAR

Elderly people's perceptions of the social and caregiving functions of robots have proven to be of considerable importance in determining the effectiveness of SAR. The acceptance of assistive robots also depends on the beliefs and attitudes of the elderly towards them.

A study by Beer et al. (2017) demonstrated a significant increase in the acceptability of robots in older adults after actual interaction with a SAR. Ferretti et al. (2018) highlighted older adults' preference for robots resembling small animals or children, with resistance towards robots resembling the human face such as the *CB2* baby robot.

As part of the aforementioned *Robot-Era* system to support the independence and safety of the elderly, its acceptability was investigated (Cavallo et al., 2018). Positive perceptions were mainly influenced by the aesthetic appearance of the robots, which increased their acceptability.

An example of a successful robot is *Vizzy*, designed to promote motor training in the elderly, with specific physical characteristics to facilitate interaction. A study (Avelino et al., 2018) showed that acceptance of *Vizzy* was favored by its ability to move its head in a way that encouraged spontaneous participation, especially in groups, although some users initially experienced anxiety.

From the qualitative analysis conducted by Daniele et al. (2019) found that open-mindedness towards technology, and expectations regarding functions such as cleaning, health monitoring and sociability influence the acceptability of robots by older adults.

Randall et al. (2019) highlighted the importance of the correct use of SARs and showed a correlation between positive attitudes towards robots and the actual intention to use them. Positive feedback has been obtained with the Mini robot, appreciated by the elderly for its ease of use and the motivation it offers in daily activities.

Lee and Naguib (2020) conducted a study on the acceptability of a soft robot among older adults, showing that older adults perceive it as easy to use, useful, acceptable, and friendly, without feeling anxiety, and express the significant intention to use it. However, the authors suggest the integration of further tools, based on neuroscientific methods, for future research.

Bahrmann et al. (2020) studied the MAKS therapeutic program using SAR platforms in geriatric facilities, highlighting a positive perception of the elderly and a lightening of the workload of care professionals, which allows them to dedicate more time individually to each user.

The systematic review conducted by Vandemeulebroucke et al. (2021) identified six main themes related to older adults' perceptions of SAR: general attitudes and feelings about robots, their appearance, the tasks expected of them, perceived usefulness and ease of use, intention to use them. Older adults are generally relatively open-minded towards the use of assistive robots, with positive feelings and intentions for future use, especially for physical assistance.

He et al. (2022) examined theoretical models and impact factors of technology acceptance among older adults. They noted improvements in the acceptance of assistive robots, highlighting the importance of customizing features. Experimental models such as *TAM (Technology Acceptance Model*: Davis, 1989), *UTAUT (Unified Theory of Acceptance and Use of Technology*: Venkatesh et al., 2003), and its extension *ALMERE* (Heerink et al., 2010), allow the evaluation of psychological states of the elderly in accepting new technologies.

A survey aimed at investigating older adults' preferences for assistive robots focused on factors influencing robotic acceptability, applying the methods of *Human-Centred Design and Ergonomics*. These methods can aid in identifying actual users' needs and translating them into design solutions, with "stronger involvement of stakeholders during the design phases of robots to promote a deeper understanding of those people's needs and insights that cannot be collected by quantitative surveys" (Becchimanzi et al., 2022, p. 18). Burema (2022) conducted extensive research on older adults' perceptions of their interaction with technology, particularly social robots.

The main purpose expected from SARs in assisting the elderly is to support them in improving themselves and their physical and social condition.

SAR can reduce loneliness and social isolation, helping to manage apathy and depression. However, older adults' negative opinions about robots and their unfamiliarity with them may impact the effectiveness of such interactions; in fact, from the review by Watford-Spence (2022) it can be deduced that beliefs towards robots were initially quite negative and this has a relationship with acceptability. To address this issue, we can consider the acceptability of the robot right from the design stages, taking into account the experiences and opinions of older people. An approach to improve the interaction between older adults and SARs was investigated using the self-disclosure technique, which led to an increase in interactions and an improvement in their quality, as demonstrated in the study conducted by Igarashi et al. (2022).

Research on the acceptability of assistive robotics is not limited to elderly users but also involves caregivers, family members, and healthcare workers.

The perceptions of healthcare professionals on the aforementioned *Stevie* and *Pepper* robots used in nursing homes were explored (McGinn et al., 2019; Carros et al., 2022) revealing a limited impact on the operators' workload but positive effects on their job satisfaction. Tietze and McBride (2020) confirmed that the use of the *Moxi* robot allows nurses to spend more time with patients, offering valuable support in the hospital context.

Tobis et al. (2023) demonstrated that acceptance of social robots is related to perceptions of several dimensions of robots, such as appearance, animation, pleasantness, intelligence, and perceived safety. Significant differences were found between older adults and healthcare workers, underlining the importance of involving older users in the design stages of social robots, to address their specific needs and ethical issues, improving the effectiveness of such technologies.

6. Socio-cultural aspects

The *CARESSES* project, described by Papadopoulos et al. (2020), considered how culture impacts improvements in well-being when it comes to robotic care in care homes. A "culturally aware" robot was used to provide personalized assistance based on the user's culture. Although the sample was limited, preliminary results from this project indicated that the cultural competence of robots can positively influence the well-being of older adults. In a subsequent study, Papadopoulos et al. (2022) confirmed the importance of the cultural component of robotics in improving the psychological well-being and quality of life of elderly people in nursing homes.

To explore cultural variables in the acceptance of assistive robots, Fracasso et al. (2022) conducted a study on 197 participants from Italy and Germany: the most relevant differences between the expectations of Italians and Germans concern extrinsic aspects such as financial support from the national healthcare system.

A study conducted by Fraune et al. (2022) compared how robots could be used as facilitators to reduce social isolation among older adults in Japan and the United States, through the participatory design method. Cultural differences lead Americans to prefer telepresence robots, while the Japanese have shown interest in animal-like robots. However, both cultures have recognized the ability of robots to connect people socially, although doubts have arisen about the possibility of sharing desired experiences and some skepticism persists in this regard.

Cultural aspects affect attitudes towards technologies, and in particular on robotic ones, through learned cultural models. In this sense, the study conducted by Schneider and Bousbiat (2023) is interesting, involving a sample of Austrian "baby boomers" (born between 1956 and 1969), now adults, in the use of a robot-coach for assistance with daily activities. These people accustomed to technologies since childhood, showed an ease of use exceeding initial expectations, although the need emerged to train the target population of technological and robotic devices to overcome persistent prejudices regarding their use.

Another research conducted in Japan by Igarashi et al. (2023) examined possible biases in the selection of participants and therefore the representativeness of the samples used for the study and use of social robots with the elderly. To avoid the risk of bias arising from the recruitment method, an increase in the sample size and a stratified analysis for different personality traits and cultural backgrounds are suggested.

Questions have been raised about the equity of VR, which should be accessible to all elderly people regardless of their socio-economic and cultural conditions (Ramalho et al., 2024).

To ensure that new technologies and assistive robotics are truly effective for older people from different cultures and social strata, inclusive and culturally sensitive approaches are needed. This requires collaboration with local experts, adaptation of technologies to the specific needs of different communities, and respect for cultural traditions and values. There is also a need for social measures, and economic support for both the production and purchase of technologies, to avoid the potential digital divide or disparities in access to and adoption of these technologies between different socio-economic groups or between cultural backgrounds within the elderly population.

Further empirical research on these aspects is needed to better generalize the results obtained so far in different cultural and economic contexts.

7. Critical issues

The reviewed scientific literature shows that new technologies and assistive robotics represent a promising frontier for improving the quality of life for the elderly. However, to take full advantage of these innovations, existing limitations and gaps must be addressed and mitigated.

Among the main limitations are affordability, technological complexity and usability by older people and their caregivers, maintenance, support, and technical assistance, which are more difficult in less developed areas. This can negatively affect the reliability and continuity of services.

Regarding the development of technologies, a critical issue for many of them is the lack of adequate customization, which must adapt to health conditions, physical abilities, and personal preferences.

Another critical issue is the compatibility of technologies with existing systems of care: lack of integration can lead to inefficiencies and a decrease in the overall effectiveness of care.

Also critical is the training of caregivers; they may not be sufficiently trained to use assistive technologies effectively, requiring investment in specific training programs to ensure that medical and caregiver staff can take full advantage of the potential of new technologies.

Finally, the inherent issue of privacy protection during the monitoring phases should not be overlooked. These continuous monitoring procedures improve the safety of the elderly, allowing rapid intervention in emergencies. However, this raises concerns regarding privacy during surveillance, as medical and personal data may be vulnerable to breach.

For example, camera-based Ambient Assisted Living (AAL) technologies installed inside homes are valuable support for the elderly who wish to maintain their independence despite age-related issues. Privacy is mentioned prominently among the main categories influencing technology acceptance in the review by Mujirishvili et al. (2023), as users are concerned about third-party use of their sensitive data. The study by Maidhof et al. (2023), considering three scenarios (household activity, social activity, and intimate activity), shows that the acceptability of video-based AAL technologies depends on the activity being monitored. In particular, people tend to have a greater need for privacy for intimate activities.

Ravi et al. (2024) classify visual privacy preservation methods into five categories: blind viewing, secure processing, data hiding, visual obfuscation, and anonymization. Among these, visual obfuscation (perceptual and automatic) is particularly beneficial, although creating systems that provide high privacy in real time remains an open challenge. Research in this field is still in its infancy, and investigation into reliable privacy systems needs to be implemented, offering a valuable resource for designers and practitioners dealing with the psychological impact of these technologies on the target population.

8. Ethical aspects

An increasingly relevant topic in the context of innovative assistive technologies is ethics, given the multiplicity of concerns and risks linked to the use of robots in interaction with humans.

This problem, of a general nature regarding all technologies based on Artificial Intelligence, has been prompting interventions and regulation by supranational bodies and agencies (e.g., by the European Union).

Principles established by the European Commission (2019) regarding the ethics of Artificial Intelligence include human intervention and oversight, technical robustness and security, data confidentiality and governance, transparency, diversity non-discrimination and equity, social and environmental well-being, accountability i.e. minimizing adverse effects. These principles have been applied in the Regulation on the Use of A.I. approved by the European Parliament (2024). They are of particular relevance to vulnerable populations such as the elderly and cover essential aspects such as security and protection of personal data and privacy discussed in the previous paragraph.

A study conducted by Battistuzzi et al. (2018) examined the ethical issues related to the use of technologies with the elderly population, focusing on the application of *Value Sensitive Design* (VSD) from the initial stages of the design process. Some ethical macro-themes emerged, including autonomy, well-being, privacy, security, and dignity, which were further divided into "ethical labels" that reflect the importance assigned by users to all the activities of artificial agents in various scenarios, underlining the ethical relevance of every interaction.

Kim et al. (2022) in a study based on the *Human Centered Artificial Intelligence* (HCAI) approach, examined the ethical issues associated with SAR providing home care to frail elderly people, with the involvement of professionals such as nurses and healthcare workers.

Particular emphasis was given to the practical and functional issues of SAR for the elderly.

The robot's size, alarm functions, and error management, were considered ethically relevant factors. Both studies underline the crucial importance of ethics in the implementation of assistance robots for the elderly, highlighting the need to carefully consider complex ethical issues such as autonomy, safety, and personal dignity when designing and using these innovative technologies.

Much consideration must be given to the ethical aspects not only of robotics (on which there is ample attention) but more generally of Intelligent Assistive Technologies and their interactions with the cultural and value aspects of users.

Together with the ethical aspects, those relating to spirituality, which are important for many elderly people, should be considered. According to Trothen (2022), attention to the spiritual implications of the assistive technologies for aging persons can help not only to engage in more robust ethical analysis, but to surface assumptions regarding the meanings of successful aging.

9. The role of the developers of new technologies for elderly

As a result of what has been said about critical issues and ethical problems, designers and developers assume a major role. The effectiveness and acceptability, including the ethical acceptability, of technologies, safety, and security, require a deep understanding of misuse risks and meticulous design. As noted, among the variables to be taken into account in programming are

- *Usability* - the assistive technology must be intuitive and easy to use;
- *Predictability* - the system should be predictable and consistent, allowing users to anticipate its actions and interact with it safely and confidently;
- *Simplicity* - the user interface should be simple and intuitive;
- *Efficiency* - task execution time should be as short as possible, minimizing user frustration and fatigue;
- *Sensory feedback* - such as the use of voice prompts, appropriately modulated in terms of speed, frequency, pitch, tone, and volume;
- *Ergonomics* - the space of movements required to use the system should be compatible with users' physical capabilities, ensuring comfort and minimizing strain;
- *Customization* - assistive technology should offer possibilities for personalization, allowing users to adapt the system to their needs and preferences;
- *Design,* both aesthetic and functional - plays a key role in the acceptance of assistive technology. For example, elderly people's preference for friendly-looking robots has been highlighted, suggesting that robots with anthropomorphic or pet-like shapes, such as Paro (Kang et al., 2020), are more acceptable, and facilitate interaction and effectiveness on quality of life.

Specifically regarding VR technologies for the elderly, Bradwell et al. (2024) offer important and useful information for developers, as participants in their study stated a preference for realistic VR experiences with minute details and virtual visits to real-world places, conversely disliking more cartoony and unrealistic models.

Potential users were also directly involved in evaluating specific technologies for the elderly in Halicka's study (2024). The highlighted preferences contribute to understanding the role of technologies in improving the quality of life of the elderly, taking an interesting look at the promotion of sustainable development and their impact at the social and ethical levels.

The field of assistive technology thus poses unique and complex challenges to designers and developers, requiring deep synergy among multidisciplinary professionals, such as engineers, computer scientists, and psychologists (Bardaro et al., 2022; Zeghloul et al., 2020). To create effective and truly useful solutions, it is crucial to have a deep understanding of the needs and limitations of the target users (Kachouie et al, 2014).

Psychology can offer a valuable lens through which to understand the cognitive, physical, and social challenges that users experience daily, providing crucial information about the barriers that users face, and how technology can help overcome them, through appropriate individualized device programming.

10. Conclusive remarks

In summary, using new technologies and assistive robotics for the elderly represents a promising horizon for improving their care. However, it is critical to explore and resolve the challenges related to usability, acceptance, and social and ethical implications of these technologies.

Among these, we highlight the limited attention to economic evaluations of the effectiveness of assistive technology, the need for standardized protocols to guarantee a common language between users and researchers, the lack of training and skills in the use of devices, which can lead to improper use causing inconvenience to users (Muthu et al., 2023). Furthermore, the importance of identifying which devices are appropriate for individual cases emerges, to best ensure the quality of its use.

To encourage the acceptance of these technologies, the *Smart Aging Research Group* (Street et al., 2022) highlights how particular attention must be paid to autonomy, privacy, other legal aspects, and ethical principles.

Regarding the research methodology, the evaluation of effectiveness is often carried out through surveys, which can be influenced by the prejudicial positions of users, generating potentially biased feedback. The integration of neuroscientific methods to integrate and validate self-reported measures is suggested (Lee et al., 2020).

An increase in meta-analytic research aimed at identifying potential moderators of the effects of interventions using VR and SAR applied to different people and contexts, is also desirable.

Finally, we highlight the need to develop multi-centric and multidisciplinary research capable of responding in an integrated way to the challenges posed by the applications of new technologies in assisting the elderly population, in different areas and social contexts.

Promoting greater collaboration among engineers, physicians, caregivers, and the elderly themselves, could facilitate the development of more effective and acceptable technological solutions. The importance of involving caregivers (structured and unstructured) and families is underlined, as they have a significant impact on the effective use of technological devices.

It is essential to promote a holistic approach that integrates technology with human care, ensures accessibility, provides appropriate training for caregivers, and respects the privacy of the elderly. Only in this way will the full potential of assistive technologies be realized, significantly improving the lives of older people and their well-being.

CRediT authorship contribution statement

Mariagrazia Costanzo: Writing – review & editing. **Rossana Smeriglio:** Writing – review & editing. **Santo Di Nuovo:** Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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