Socially Interactive Agents for Supporting Aging

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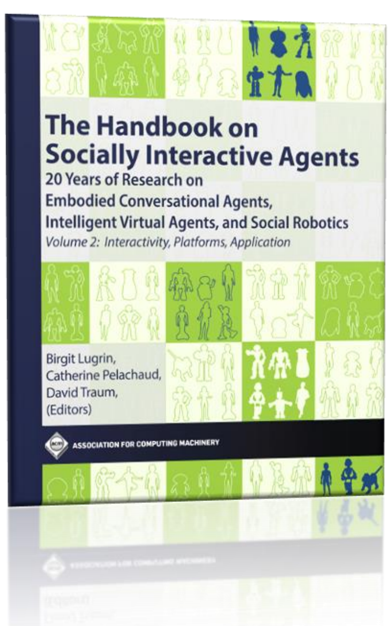

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23 Socially Interactive Agents for Supporting Aging

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23.0.1 Motivation

The average age of world's population is steadily increasing. 125 million people globally are aged 80 years or older and it is predicted that this number will change to 434 million by 2050. While many older adults are capable of living independently, there are many others that need care. For example, 50 million people are currently living with dementia (predicted to reach 152 million in 2050), which is reported as a leading cause of disability and dependency among older adults [World Health Organisation 2019].

While the increasing number of older adults is resulting in an increase in the demand for caregivers, the demographic change that is occurring worldwide is limiting available resources. By 2045, older adults are predicted to outnumber youth (i.e., population < 18 versus > 65 years of age) for the first time in history [Vespa et al. 2018]. Having an aging population has profound implications for the social, cultural, and economic systems that are needed to support healthy and holistic aging. For instance, WHO [Harris 2019] estimated that between 2006 and 2015, expenses have been around USD 84 billion to treat chronic diseases such as heart disease, stroke and diabetes; conditions that are more prevalent in older adults. 13 million new cancer cases in 2009 (largely because of global aging) had an associated treatment cost of at least USD 286 billion; this number is expected to increase to 27 million cases in 2030 [National Institutes of Health et al. 2018]. While the costs associated with maintaining wellbeing and quality of life of older adults are difficult to assess, it is clear that technological solutions for supporting aging can help with reducing the associated costs, such as enhancing wellbeing of the world's growing number of older adults and decreasing the workload on caregivers [Kachouie et al. 2014].

While there is much focus on changes in health and the associated costs that often accompany aging, engaging in meaningful activities is a key component to a good quality of life. Older adults are valuable members of society; they have a high rate of volunteerism and several studies have shown inter-generational interactions with older adults lead to positive outcomes for younger adults, such as increased self-esteem, acquiring new skills, and decrease in anxiety [Springate et al. 2008]. Supporting older adults' ability to engage in the activities that provide fulfillment, enjoyment, and personhood is as important as supporting their health.

The increasing demands of our aging population is creating gaps in support for health and wellbeing, some of which can be filled by technological solutions, particularly those that disproportionately affect older adults. For example, while COVID-19 led to isolation among both younger and older adults, the impact was higher for older adults for many reasons, such as the greater risk of catching the virus in long term care homes, greater average fragility of older adults (therefore more susceptible to poor outcomes), and relatively less access to communication and connectivity technology. Therefore, this situation led to increased social isolation, including among older adults who were not previously socially isolated.

Socially assistive agents have the potential to help fill gaps caused by the increasing demand for support, as well as situations that affect older adults' mental health. Socially assistive agents are computer-driven technological entities that are able to interact with a person in a socially engaging manner [Hegel et al. 2009]. Increasing technological advances are enabling assistive agents to have a positive impact on several aging-related challenges that can significantly affect people's independence and their quality of life [Matarić and Scassellati 2016], such as physical, cognitive, emotional, and social challenges [Saez-Pons et al. 2015, Wang et al. 2014]. While assistive agents are not a replacement for human companionship, there are several ways technology can be used to support older adults and promote greater feelings of engagement, independence, and inclusion. For example, by increasing older adults' independence (e.g., increase healthcare support or support remote contact with their families to reduce isolation) [Moyle et al. 2018], acting as companions to reduce loneliness [Banks et al. 2008], encouraging and increasing engagement of older adults with others [Šabanović et al. 2013] as well as in activities [Abdollahi et al. 2017, Khosla et al. 2012], and supporting mental health [Shibata and Wada 2011].

Despite these positive outcomes, society's attitude towards social robots is not always positive and people's attitude towards social robots has been reported to have become more negative over years [Gnambs and Appel 2019]. This may be in part because many people worry social robots are poised to replace human contact, rather than viewing them as complementing existing resources and enriching experiences. A study conducted during the social isolation period of COVID-19 showed that those who reported any change in their lives due to COVID-19 (either positive or negative) had a positive perception change about the advantages of the social robots [Ghafurian et al. 2021b]. This could be due to the fact that COVID-19 represented a situation in which in-person interactions where not possible and emphasized the potential benefits of social robots. Furthermore, the COVID-19 situation, while unique in nature, could be representative of many other circumstances that lead to social isolation among older adults, such as physical disabilities that may limit older adults' interactions outside their homes and family members that live far away.

The aim of this chapter is to: (a) provide an overview of the state of the art of assistive agents designed with the goal of supporting aging and improving older adults' quality of life, (b) present existing methods and approaches for design, development, and evaluation of assistive agents, including important considerations for implementing them, and (c) discuss existing challenges and provide directions for future work in designing assistive agents for aging.

We start with a few definitions of terms used in this chapter. First, we define what we mean by "older adults". While WHO [World Health Organisation 2020a] uses "older adults" to refer to adults over the age of 60, it is defined differently between countries (e.g., 65+ in North America) and organisations. In this chapter we do not refer to any specific age range; our focus is rather on a broad range of people with different needs and abilities who have experienced aging, ranging from healthy older adults to those with multiple morbidities.

In terms of "assistive technologies", WHO [World Health Organisation 2020b] has defined guidelines and definitions to establish whether or not a system/device can be considered as assistive. Specifically, assistive technologies are defined by the Individuals with Disabilities Education Act (IDEA) as "Any item, piece of equipment or product system… that is used to increase, maintain or improve the functional capabilities of individuals with disabilities". The aim of assistive technologies is to help people to reach their goals such as improving independence, facilitating social participation by fostering inclusion, mitigating impairments and other health-related conditions, and increasing quality of life.

Furthermore, "assistive agents" are entities that are situated to assist a person in any task or activity. Raïevsky and Michaud defined a situated agent as a "Physical or virtual entity which is situated in a dynamic, quasi-continuous environment, which it perceives through sensors and into which it operates autonomously". The type of assistance can be different depending on the context, for example, it can vary from different levels of acting upon the environment or providing information [Breazeal et al. 2016a]. Here, we define assistive agents accordingly, as physical or virtual entities that are situated in dynamic environments with the goal of assisting a person.

While there are several applications that assistive agents can help older adults with, a variety of factors can affect the success of these agents. This chapter discusses such factors and emphasizes design approaches that can minimize challenges related to their design and implementation while maximizing the likelihood of adoption by assistive agents by their users.

23.0.2 History and Overview

Older adults' wellbeing can be affected by many factors such as their health, mental state, and ability to live independently [Boger 2014]. Therefore, assistive agents can be designed to assist older adults in many different contexts and in a variety of tasks. For example, a recent review of the existing assistive robots for supporting older adults with dementia has identified

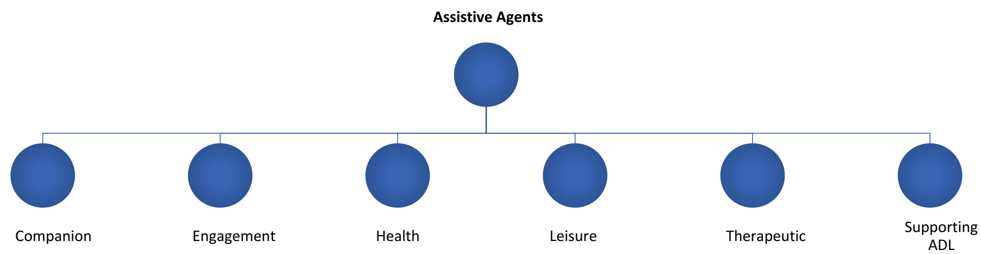

Figure 23.1 Categories of use for assistive agents

five categorizes for assistive robots' applications: (1) Companionship, (2) Engagement, (3) Health, (4) Therapy, and (5) Activity of Daily Living (ADL) [Ghafurian et al. 2021c]. The reader can also see [Shishehgar et al. 2018] for a proposed categorization in a more general context of robotic technologies for older adults.

In this chapter, we will discuss the applications of assistive agents for supporting aging in six different categories, as shown in Figure 23.1. The first category, *companionship*, are agents that are designed with the goal of providing companionship, and in most cases with the goal of reducing social isolation and loneliness. These agents could help with a variety of tasks, such as talking with older adults, playing music or videos, showing pictures, or reminding people about their tasks or calendar events. COVID-19 has emphasized the potential role of intelligent agents and social robots that are designed to provide companionship during a period of self-isolation and social distancing where human contact may be hard or impossible [Ghafurian et al. 2021b].

The second category, *engagement*, represents assistive agents that are designed to increase engagement of older adults with technology, in activities, or with others such as therapists, family, and friends. The third category, *health*, represents agents that directly promote health such as agents that motivate exercise, a healthy living style, and suggest specific diets. The next category, *leisure,* represents agents that provide older adults with a type of entertainment, such as playing games.

While agents in the above four categories can be adopted by most older adults, the agents in the last two categories, *therapy* and *ADL support*, are those that support people with specific needs. Therapy represents agents that provide a type of mental or physical therapy (e.g., pet or music therapy), and agents in the ADL support category are those that are designed to assist an older adult with an activity of daily living, either by providing cues about the next steps of an activity (e.g., washing hands) or by physically assisting with that activity.

Other categorizations have been used to explain the role and nature of agents. For instance, agents can be classified by considering their nature: physically embodied agents, virtual agents, and voice assistants. Physically embodied agents (robots) can be distinguished from virtual agents because they have a physical embodiment (i.e., hardware based agent). A virtual agent is defined as a graphic entity that simulates behaviors (human-like or not) and actions in the real world [Calvo et al. 2015]. Virtual agents are usually on a screen of some type.

Voice assistants (also known as smart speakers or voice controlled devices) have been gaining attention during the last decade [Stigall et al. 2019]. Voice assistants (1) interact primarily through voice commands (input), (2) are always connected to the internet, and (3) communicate with the user through audio (output). Voice assistants differ from robots as they are equipped with limited hardware capabilities (e.g., stationary location, sensing capabilities limited to record voice, battery life, etc). However, voice assistants can be interfaced with robots and smart devices for home automation systems to extend their functionalities. Although research in this field is still in relatively early stages [Pradhan et al. 2018], there is clear potential for these devices to provide assistance in tasks such as making remote calls, providing medication reminders, and controlling a smart home.

Assistive agents and robots have been developed to support multiple contexts. For example, animal-like robots have been successfully used to provide pet-therapy [Shibata 2012]. One of the most well-known animal-like robots that has been used successfully in the older adult context is the PARO robot, which is a seal-like robot that has been successfully adopted by many older adults with dementia. Human-like robots have been used in other contexts, such as providing music-therapy or language-related therapies [Martín et al. 2013].

Agents for promoting healthy living have been used for a variety of health-related tasks ranging from motivating healthy living habits (e.g., to walk and exercise) [Khosla et al. 2014] to provide advice about diet [Khosla et al. 2012]. However, using this category of agents to support aging has gained relatively limited attention. This may be because of the challenges in designing effective agents in this context.

Agents have also been proposed to assist with specific activities, such as a hand-washing system that assists people with dementia in washing their hands by providing audio/visual support about the next step in the task [Malhotra et al. 2014] and a meal-time assistant that prompts people with dementia to eat their food and helps them with the process of eating a meal [Derek et al. 2012]. However, designing agents that successfully help with performing activities of daily living is very challenging as the agents need to perceive the user's actions and its environment accurately to provide timely and contextually appropriate support.

Agents (and in particular social robots) have been successfully used to increase social engagement of older adults [Perugia et al. 2017, Šabanović et al. 2013], and to provide companionship [Mannion et al. 2019, Odetti et al. 2007]. Companionship agents have been evaluated with older adults with different conditions such as cognitive disorders, dementia, stroke, and depression, and in a variety of different settings, such as long-term care homes, day-care centres, and individuals' homes. Most of the agents have been successful in supporting aging and have shown positive improvements in older adults' quality of life in many domains. For example, assistive robots used in care centres not only increased older adults' engagement in activities [Rouaix et al. 2017], but also improved their engagement with other residents [Šabanović et al. 2013] and reduced depression [Shibata 2012]. In the context of therapy, both short-term and long-term effects of social robots have been investigated; however, in many contexts, the long-term effect of these agents are unknown, due to multiple challenges involved in conducting long-term studies. Some of these challenges are further discussed in section 23.0.5.

Another field that has contributed to the development of assistive agents for supporting aging is serious gaming. In this area, games are designed with objectives that go beyond entertaining players, such as promoting healthcare, education, and training [Michael and Chen 2005]. Serious games that support aging have shown measurable benefits in physical fitness [Kappen et al. 2019], rehabilitation [Proença et al. 2018], and cognitive functions such as memory [García-Betances et al. 2015], spatial orientation [Gamito et al. 2017], executive functions [Nouchi et al. 2012] and slowing down cognitive decline [Lau et al. 2017]. While researchers have shown positive potential of using games for specific physical and cognitive interventions, more research and evidence is needed to allow for: (1) establishing strong theoretical foundations, (2) better design experimental protocols, and (3) greater focus on user experience (rather than system usability evaluations) to better understand motivation, engagement and long-term adoption [Zhang and Kaufman 2016]. Furthermore, research in the field of serious games to support aging has primarily focused on healthcare support, such as therapeutic rehabilitation and cognitive training. As games have demonstrated their potential in alleviating isolation and supporting social well-being [Li et al. 2018], these are areas relevant to aging that warrant more attention. Beyond therapeutic uses, serious games could play a decisive role in connecting older adults with their family beyond traditional video-calls and messaging applications; games can be used as the medium to create meaningful connections among grandchildren and grandparents [Boger and Mercer 2017]. Further, for the purpose of entertainment, gaming profiles tailored for older adults have been created, revealing the importance of specific game design aspects such as aesthetics (e.g., nostalgia, contemporaneity) and mechanics (e.g., musical play, autobiographical) to foster meaningful game play [De Schutter 2017].

To conclude, while social robots have been shown to be a suitable solution in many application areas, technology adoption and long-term use are still relatively low due to the challenges involved in running longitudinal studies in this context.

23.0.3 Models and Approaches

It is important to involve older adults when designing assistive agents if they are to successfully support ageing. In other words, as with all intended user groups, it is important to design *with* them instead of *for* them [Lazar et al. 2018]. Other than ascribing agency to users [Tholander et al. 2012] and empowerment [Galliers et al. 2012], this means accessing and complementing their needs, values, and abilities, which can be accomplished through *user-centered design methods*.

User-centered design methods, such as participatory design and co-design [Sanders and Stappers 2008], provide researchers and developers with rich insights that enable them to create a successful product [Zimmerman et al. 2007], based on real user needs instead of designers' assumptions. They can also ascribe agency [Tholander et al. 2012] and empowerment [Galliers et al. 2012] to users by creating products that clearly reflect them. Participatory design is when relevant stakeholders are involved in the design process to get a feel for and incorporate the user perspective. Participatory design is becoming more commonly used in research in general; indeed, it is becoming a requirement by several funding agencies for projects involving human participants. Co-designing is a more intensive level of participatory design that implies a very committed and early involvement of the targeted population to generate an empathetic perspective that will facilitate the understanding of needs, motivations, preferences, attitudes and limitations in designing agents for supporting aging [Smarr et al. 2014].

As with other contexts, involving older adults in the design process is an important aspect of developing assistive agents that can successfully help older adults [**?**]. User-centered design and participatory design have been gaining more and more attention in designing technologies with this audience [Duque et al. 2019] as they can provide more holistic and direct insights into older adults' needs and motivators to use and adopt assistive agents.

The convergence of an amalgam of these techniques and approaches is a clear response to a design manifesto suggested by Donald Norman arguing for a more integrative and diversified process for product design [Norman 2013]. Therefore, the classical, structured and sequential technology-driven design-prototype-test cycle applied in product design is hardly suitable for the creation of novel assistive agents targeting older adults [Daly Lynn et al. 2019]. For example, many of the common assumptions about technology usages may not be applicable for older adults due to a difference in older adults' mental model of agents and their limited previous exposure to such agents.

Developing assistive agents to support aging is and should be highly multi-disciplinary. The design process itself requires the use of several techniques and approaches from areas such as product design, human-computer/robot interaction, and system design. The preliminary research, requirement elicitation, ideation, design, testing, and validation stages should normally consider a variety of techniques and tools to create suitable solutions that can properly accommodate older adults' needs. This includes the consideration of those who may be providing formal (i.e., clinical) and unpaid (i.e., family and friends) care for them, if appropriate.

Well-established techniques for user-centered design include shadowing and observational processes, emotion assessment, self-reporting tools (e.g., diary studies, focus groups, surveys, and interviews), user modelling approaches (e.g., user personas, user journey maps, scenarios, card sorting) and designer analysis (affinity diagrams, use cases, user matrices) [Still and Crane 2017]. Despite being time-demanding, the co-design process enables researchers to have a more solid end-user model, as well as valuable information about how to design assistive agents in a way that it meets the expectations, needs, and preferences of older adults [Munoz et al. 2019]. This may in turn save time later with more appropriate, targeted, and effective designs.

Table 23.1 shows a summary of the common methods widely used to design socially assistive agents. Five methods have been highlighted in the literature: (1) *focus groups*, which help researchers to learn more about older adults' concerns, needs, and perspectives as well as come up with new ideas by generating discussion among the participants; (2) *interviews*, which help with understanding of people's individual experiences, concerns, and perspectives; (3) *questionnaires*, which provide researchers with a structured way of exploring questions by reaching out to a larger number of participants that can be from a diversity of geographic regions; (4) *ethnographic field studies*, which allow researchers to gain rich insight on participants' behaviour and the reasons behind their actions (e.g., interactions with the agents); and (5) *case studies*, which enable researchers to obtain detailed information that may not be possible to obtain through other methods.

There are different advantages, challenges, and considerations for using these methods with older adults, and examples of research that used each method are described in Table 23.1. For instance, when running focus groups, the researcher should consider important accessibility aspects of older adults, such as ensuring that participants can hear each other clearly and correctly, as well as ensuring that they are physically and mentally comfortable when sharing their views. Interviews, on the other hand, can be carried out remotely and offer greater flexibility in time and location when compared with the focus group, but are more time intensive and cannot support group discussion. Surveys have good opportunities for wide outreach, but may not support clarification on questions or answers that may be confusing. For all of the techniques, the researchers need to be realistic and sensitive to older adults' preferences regarding the length of the study, the wording used, and any technologies that are employed; this includes considering when to run the study so as to align them with older adults' preferences.

One important decision in the design process is the choice of the interaction methods and modalities. Examples of interaction types are speech, tactile, non-verbal and verbal cues, and emotions. In general, choosing the right interaction method(s) for any intelligent system is crucial and is decided according to its applications. The choice of interaction methods becomes even more critical in technologies aimed at older adults, due to possible changes in abilities caused by aging, for example changes in hearing, vision, and/or memory function. Therefore, it is important to: (a) include multiple interaction approaches as opposed to relying on one, as some interaction approaches might work for some individuals but not others, (b) implement the interaction approaches in a robust way, as failures could lead to frustration and and abandonment of the agent, and (c) carefully match the interaction modality to the intended goal; in other words, the technology must align to the task people want to do in a way that makes sense to them rather than employing a technology simply because it is new or at-hand.

While the performance of assistive agents can significantly affect their usability, reducing errors is challenging when it comes to designing assistive agents. There are many technical aspects that can affect the performance of an agent and the abilities of the people who use them and the contexts in which they are deployed are broad. To appropriately assist older adults, an agent should be capable of understanding its environment and users (see **??** for examples). That is to say, depending on the application, multiple aspects of the agent need to be properly implemented. For example, if the agent needs to detect objects in the environment or track people, techniques in computer vision should be used in a way that errors are minimized under different environmental conditions (e.g., lighting). Natural Language Processing techniques need to be carefully used, especially in conversational agents, so they can accurately understand the verbal cues and users' commands. This can be extra challenging as older adults often have altered speech due to changes in their soft palate that occur naturally with aging as well as a greater likelihood of having a confounding condition, such as dementia or Parkinson's disease.

Table 23.1 Common methods for designing assistive agents; advantages, challenges, and considerations are based on [Dix et al. 2003, Drachen et al. 2018, Hubbard et al. 2003, Suryani 2013]

Method	Advantages	Challenges	Considerations for Older adults	Example
Focus Group	Helps generate new ideas by encouraging discussions among participants	Getting accurate information about the participants that is not affected by the others Finding a time that works for the group	Avoid long sessions and give breaks as much as needed. If there are participants with impairments, make sure they hear and understand each other. Show greater flexibility for time and location.	[Pino et al. 2015] used focus groups to understand preferences about a social robot.
Interview	In depth understanding of people's experiences, interpretations, and opinions (*why* and *how*) More flexibility in choosing the questions Hard to quantify the responses Can be used with those who have difficulty reading or writing	Does not quantify Responses might be biased and affected by the interviewer Harder to de-identify participants Harder to recruit participants compared to surveys	Be polite and patient with the responses. Show greater flexibility for time and location. Keep it short or allow breaks (use facial expression and body posture as clue for giving breaks).	König et al. [2016] conducted interviews with care-home residents and family cares to understand how to improve an assistive agent's prompts and its acceptability.
Questionnaire	Can use standardized structures to aid interpretation of results and statistical processes. Easier to recruit participants compared to interviews, verbal/telephone surveys, etc.	Hard to understand participants' feelings and emotions. Higher probability of getting dishonest answers	Questions should be easy to read and the font should be reasonably large	Leuty et al. [2013] used questionnaires to evaluate a computer-based intelligent device from the perspectives of older adults and therapists
Ethnographic Field Study	Provides a rich qualitative observational insights into users' behaviors and the rationale for their actions	Cannot be generalized and cannot quantify aspects of behaviours and attitudes Data reported might be biased depending on the researcher More concerns about confidentiality and harder to de-identify data	Be sensitive to older adults' routines and do not disturb it.	Forlizzi et al. [2004] conducted an ethnographic study of older adults living independently in their homes to understand the role of assistive robots in living independently longer
Case Study	Provides more details about a phenomenon It allows understanding of social situations	Data reported might be biased depending on the researcher Results cannot be generalized Mostly rely on subjective data Harder to de-identify data	Be sensitive to older adults' routines and do not disturb it.	Walsh and Callan [2011] conducted case studies (along with focus groups and interviews) to understand older adults' preferences and acceptance of information and communication technologies

Data connections should be robust or asynchronous (to avoid undesirable situations such as delays) and data must be encoded and stored in a secure way in order to ensure that the privacy will not be violated by the use of assistive agents. The agent itself should be also designed in a way that it is safe for older adults to use, as safety is a key for the usability of the interactive agents, especially robots [Dautenhahn 2014]. For example, as falls are common among older adults and can have very serious consequences, researchers should ensure that the agent does not introduce a tripping hazard.

After designing and developing a socially interactive agent, the next question is how to properly evaluate it. There are several different evaluation methods that can be used; finding the proper method highly depends on the task and the users. For example, the researcher should ask: (a) what task(s) should be selected and how to present it/them in a way that represents real-life settings? and (b) what is the best communication approach to use? (e.g., do users have any specific disabilities that might prevent them from answering questionnaires, getting involved in discussions, or expressing their opinion). The most common evaluation methods for socially interactive agents include, but are not limited to, validated methods such as the system usability scale and questionnaires assessing different aspects of agents (see [Ghafurian et al. 2021a, Saez-Pons et al. 2015, Saunders et al. 2015, Syrdal et al. 2015] for examples), standard tests that measure effects on participants, such as their mood, depression level, loneliness, etc. (e.g., see [Shibata 2012, Wada et al. 2005]), using open-ended questions and scenarios (to understand effects in a wider context; see [Syrdal et al. 2014, 2015]), observations outside the experimental settings [Sabanovic et al. 2006] (e.g., using activity logs; see [Webster et al. 2015]), and video-based studies (e.g., see [Walters et al. 2011]). Some of these methods might not be as representative as direct interactions, but can allow researchers to evaluate the systems with a larger and more diverse range of participants.

Regardless of the evaluation method, it should be comprehensive, or in other words, the designers need to make sure that it covers evaluating the different aspects of the agents that are of interest. For example, Breazeal et al. [2016a] suggested six important factors when evaluating social robots (which can be generalized to other types of agents):

1. Positive/negative usefulness, i.e., whether participants express that the robot made tasks easier/harder, and whether specific aspects of the robot were easy/hard to use.
2. Every-day experience, i.e., whether people were interested to use the robot outside of the experimental setting.
3. Scenario capability, i.e., whether participants refer to specific capabilities of the robot in a scenario.
4. Companionship, i.e., whether the robot can provide companionship or social interactions.
5. Specific needs, i.e., if the robot can address needs caused as a result of disabilities or aging.

6. Specific difficulty, i.e., whether specific aspects of the robot are perceived to be hard to use as a result of aging or disability)

23.0.4 Considerations

There are many considerations that researchers should take into account while designing, developing, and testing assistive agents for older adults. In general, most considerations that are important in designing any intelligent agent are important to be taken into account for older adults as well. However, complexities that often accompany aging require additional considerations, some of which are discussed in this section.

First of all, it is important to account for changes in abilities that increase in prevalence with increasing age, such as impaired hearing, impaired vision, memory loss, and changes in mobility. Researchers should consider these conditions in the design of the agents, as well as when conducting studies with older adults. Some of these considerations are discussed in the previous sections and in Table 23.1.

Another important consideration when designing technologies and conducting studies with older adults, as well as for reporting the findings is to ensure that the vocabulary used to talk with and about older adults is appropriate. Words and phrases that might have negative connotations should be avoided. For example, "the elderly" is usually considered to be stigmatising since it implies that all older adults are a homogeneous, frail group. More neutral words/phrases are preferred such as "older adults" or "older persons". The same is true for addressing specific groups of people. For example, when working with people living with dementia. As dementia is a permanent condition, not an acute illness, it is important to avoid words/phrases such as "patient" (unless in clinical research) and "suffering from dementia". Instead, phrases such as "a person living with dementia" should be used. Resources such as [Australia 2020] can be valuable in learning appropriate and current terminology. We need to be cognisant that language is dynamic and changes over time, so what is considered to be acceptable will change in the future.

The design of novel assistive systems for supporting aging must include mechanisms of adaptation and individualisation. Intelligent adaptive techniques such as machine learning and control-theoretic approaches can capture valuable information collected during interactions with the agent (e.g., behavioral clues, physiological responses, emotional data, annotations etc.) and other existing data about humans' behaviours and preferences. These types of data can be used to dynamically adapt the agent's actions and customize responses [Whelan et al. 2018]. Therefore, a timely, diverse, multi-level and contextually-informed adaptation in assistive agents could greatly benefit the agent's capabilities to keep users engaged and motivated. While there is a plethora of novel learning methods based on sophisticated computational techniques (e.g., reinforcement learning, deep learning), there is limited research on personalizing the agents according to individuals' physical, emotional, or cognitive differences [Abdi et al. 2018, Matarić and Scassellati 2016] (e.g., by considering individuals' likes, dislikes, and behaviours [Dautenhahn 2007]). This largely remains an exciting area for further research.

Important factors that are required to increase adoption of technologies in older adults (e.g., trust and perception of usefulness) are shown to be influenced by social and adaptive capabilities in assistive robots [Heerink et al. 2010]. For instance, the utility of internet tools as a health resource for older adults was assessed in 1450 adults and older adults (50+) revealing how website design features such as information credibility and user-friendly interfaces may build trust among the older adults [Zulman et al. 2011]. Similar research has been performed assessing the acceptability of socially assistive agents by older adults, revealing how the intention to use is affected by variables such as perceived enjoyment and usefulness [Heerink et al. 2010]. However, more research should be done to better understand the role of important moderating factors such as willingness to use new technologies, general attitude toward technology, and knowledge required to foster the adoption of agents for assisting aging.

Another important consideration that differentiates robots from virtual agents is the concept of embodiment, which plays an important role in producing empathic experiences of social interactions between humans and technology [Dautenhahn 1997]. In a study comparing virtual agents with physical robots, it was argued that physical presence affects peoples responses more than physical embodiment in social robots [Li 2015a]. While some studies have shown that robots might be more appealing than screen-based agents in some contexts [Lee et al. 2006, Shinozawa et al. 2005], more systematic and comprehensive research with older adults is needed to better identify how the embodiment construct can be used to influence the design of assistive agents [Heerink et al. 2010]. Further, after selecting the platform, the decision of "what the agent should look like" can be also challenging, as the design space is large and a human-like design is not necessarily the best design [Breazeal et al. 2016a]. While there seems to be a preference towards human-like behaviour and appearance for companion robots [Walters et al. 2008], other examples such as PARO demonstrate the applicability of different form-factors to different application areas.

Immersive mediums such as virtual reality (VR) should also be considered in the discussion of the importance of physical embodiment in the design of assistive agents [Kilteni et al. 2012]. For instance, research has shown that the display mode (e.g., VR or flat screens) has a clear influence on aspects of the user's experience such as on positive and negative emotions as well as motion sickness [Xu et al. 2020].

Robots are capable of carrying out physical tasks for which the other types of agents (such as virtual agents) cannot be used. Interacting with a robot can also be more natural because users might relate it to interactions with physical toys (e.g. toys they may have used in their own childhood or when playing with their children or grandchildren) or other objects as opposed to learning how to interact with a novel interface. Natural interactions can be specifically important for the success of assistive agents in specific contexts, especially in contexts such as dementia care where learning new skills may be difficult or impossible.

However, embodiment usually introduces additional costs. Not only is the average initial purchase cost higher than a virtual agent, their increased mechanical complexity means that physically embodied agents may need more maintenance. This can be difficult, a nuisance, and expensive, which can discourage the use of this type of technology. Thus while physically embodied agents have the potential to assist with many tasks, as with any technology, the benefits of their implementation and ongoing use must clearly outweigh their costs.

Researchers and designers often "over-engineer" solutions by using an excessive amount of emerging and trending technologies. This can make the resulting solution overly complex and less robust, which translates into greater costs with unstable or undesirable performance. When it comes to the possibilities of including robots in our lives, Norman argues that social aspects of interaction are critically more complex than the technical ones, "...something that technology-driven enthusiasts typically fail to recognize" [Norman 2005]. That is to say, empowering agents with proper social abilities is a complex problem and may require elegant solutions that are intuitive and direct.

In a recent review of various robotic technologies created to assist older adults, one study concluded that the most effective robots (e.g,. effectiveness defined by the level of improvement in outcome measures once compared with control groups) were robots for companionship and telepresence [Shishehgar et al. 2019]. Companion robots such as Paro, which has a balanced set of relatively simplistic sensors/actuators, have demonstrated more positive effects on older adult's wellbeing (e.g., mood, anxiety) than other existing, more complex robots [Abdi et al. 2018]. This might be due to the simplicity of creating reliable companion robots, as compared to social robots in other categories, which require a comprehensive sense of their environments (e.g., those helping with an activity of daily living). Therefore, the design of assistive agents targeting social and healthcare benefits for older adults should be focused on producing solutions with pointed and meaningful features if they are to support accurate and consistent functionality.

The concept of *zero-effort technology* (ZET) can help researchers to explore targeted and appropriate solutions. ZETs are a "class of technologies that operate and provide support with little or no perceived extra physical or mental effort by the people who are using them" [Mihailidis et al. 2011]. In other words, a ZET enables a person to do the task they want to achieve without them having to focus effort on operating the technology itself; the technology is aligned to and complements the abilities of the user perfectly. In this way, the user does not have to think about how to use the technology, which can result in higher levels of engagement and ongoing use. This does not necessarily mean the ZET does tasks for the user, rather it enables the user to do the task they want to do. One example of a ZETs is self-adapting upper-limb rehabilitation robots, where the robot autonomously adjusts parameters such as reaching distance and applied force to match a person's abilities as they fatigue during a rehabilitation session. Another example is ambient vitals monitoring, where objects embedded in a home are able to collect health-related data (e.g., blood pressure, heart rate, etc.) of its occupants through the day-to-day interactions with common objects (e.g., couch, chair, etc.).

Last but not least, ethical considerations are a critical aspect of designing assistive agents for any population. Researchers should carefully consider how their technology relates to ethical concepts and to employ ethically responsible development of their technology. Doing so can aid researchers in creating technologies that are more likely to: (a) be recognised by users as ethically appropriate, therefore have higher levels of uptake and use; (b) avoid unintentional duress/harm; and (c) obtain approval from ethics and regulatory boards. Some of the main ethical issues that need to be supported include autonomy, confidentiality, privacy, and informed consent Kang et al. [2010]. Amirabdollahian et al. [2013] emphasize the importance of six ethical factors — autonomy, independence, enablement, safety, privacy, and social connectedness — when designing social robots for the care of older adults. Further, Robillard et al. [2018] demonstrate five principles of ethical design backed by evidence: (a) inclusive participatory design; (b) emotional alignment; (c) adoption modelling; (d) ethical standards assessment; and (e) education and training. They also propose a set of 18 practical recommendations based on these principles. To create successful assistive agents, their creators should ensure that the decisions related to all phases of the process (from design through development and evaluation) are ethical and are aligned with social and cultural values while respecting older adults' privacy, security, dignity, and autonomy.

23.0.5 Current Challenges

There are many different challenges regarding design, development, testing, and deployment of assistive agents for aging, many of which apply to application areas and users beyond assistive agents and older adults. These challenges are discussed in this section.

23.0.5.1 Technology Acceptance

As with any population, acceptance of assistive agents by older adults can be affected by many factors. Heerink et al. [Heerink et al. 2010] have proposed a model to measure acceptance of assistive agents by older adults. This model considers two aspects: (a) factors that affect perceived ease of use and functionality of the agents, and (2) the factors related to social interactions.

As also suggested by Heerink et al.'s model, assistive agents designed for aging should be easy to interact with, have a high level of performance (which is challenging, as in many cases a successful assistant should be able to perceive people's intentions and goals to be able to adjust its assistance [Breazeal et al. 2016a]), and be able to gain users' trust. Performance becomes important in technologies related to aging because some older adults might be less technically proficient, which affects their ability to understand how the agents work or troubleshoot malfunctioning agents. Furthermore, while older adults are the fastest growing adopters of technology, they consider which ones to use more carefully than younger generations. In general, this is due to the perceived effort required for learning how to interact with a new technology, the time and effort required for maintaining it, and less of a desire to acquire new "gadgets" unless they have clear value.

Further, factors such as human-like communication and the ability of the agents to meet users' psychological, emotional, social, and environmental needs have been identified in recent reviews as important elements to aid technology acceptability [Whelan et al. 2018]. These factors, such as the capability to express/perceive emotions, to engage in *social relationship* [Dautenhahn 1995], and to use natural cues are considered to be key for an agent to be truly socially interactive [Dautenhahn 2007]. Building technology-driven agents that are impersonal can lead to a poor user experience and low acceptance from the users, even if the agents are "intelligent" and act appropriately in their environment [Dragone et al. 2015].

It is also important to consider that older adults' preferences of which socially interactive agents to use (e.g., virtual agents and social robot) might depend on the type of the task. For instance, one study showed that older adults preferred robotic assistance over human assistance for specific activities of daily living such as laundry and medication reminders (instrumental); older adults were less open to allow the robot assistance in activities for personal care [Smarr et al. 2012]. In some cases, this can be due to perception of "dehumanized care" [Sävenstedt et al. 2006], or in other words, older adults' concerns about the reduction of interactions with the family caregivers [Wang et al. 2017]. It makes sense that tasks that are perceived as more 'mechanical' have higher levels of acceptance for robot assistance compared to ones that are more personal or 'human'. This does not mean robots should not be developed for supporting tasks of a more personal nature, but it does mean that developers must be sensitive to the people's perceptions and to complement these with appropriate design choices. Furthermore, acceptance of the technology may depend on perceptions of other stakeholders than just the older adult, such as their family, friends, and care providers.

23.0.5.2 Ease of Use and Perceived Need

If the assistive agent is designed through user-centered processes and evaluated properly before being deployed, there is a much higher chance that it will be successfully adopted by the users. However, user-centred design itself can be challenging when designing assistive agents for older adults; as with any research involving this technique, locating and recruiting participants that are interested to get involved in the studies requires time and effort. If recruiting populations such as people living with dementia or from care homes, there are additional processes required to ensure that the study is safe for the participants and to get appropriate ethical and other permissions. If recruiting outside the care homes, reaching out to older adults who live independently can be challenging as well since some recruitment methods such as social media advertisements are less effective than with younger populations. Furthermore, patience and careful thought must be put into recruiting and inviting end-users to be co-creators as the participants need to be kept engaged with activities that can be sometimes overwhelming and frustrating (e.g., long interviews, multiple focus group). Since co-designing requires a series of systematic and carefully planned steps to model users and create suitable interactive solutions through iterative processes [Munoz et al. 2019], these must be carefully mapped out in advance and adapted as new information is learned in the earlier stages.

When it comes to populations with cognitive impairments (e.g., people living with dementia), there is a lack of appropriate methods and materials that can foster the active involvement needed for generating user-driven solutions rather than technology-driven "gadgets" [Suijkerbuijk et al. 2019]. This can be in part due to a general lack of researchers' expertise and desire to appropriately include older adults in research or to capture their opinions, because it may require more time and modification of methods, so that they are matched to each person's abilities. For example, self-reporting is not appropriate past the early stages and needs to be replaced by observations in the moderate to severe stages.

23.0.5.3 Trust

Even if an assistive agent achieves a high level of performance and is capable of assisting older adults, it still needs to gain and retain older adults' trust. While performance is an important factor that can increase trust, there are other factors that are shown to be effective, such as the nature of the task [Salem et al. 2015] and the affective connection between the agent and older adults.

Improving social and emotional capabilities of assistive agents is one area that has recently seen attention in the literature [Konig et al. 2018, Robillard and Hoey 2018]. In general, the importance of the affective experience is emphasized through multiple studies, which have shown that the affective experience can increase users' engagement [O'Brien and Toms 2008], improve loyalty [Jennings 2000], and increase people's enjoyment [Chowanda et al. 2016] and their cooperation with the technology [Ghafurian et al. 2019].

In dementia care, social robots are being developed to support expression of emotions, even though the set of emotions the agent can express is typically limited to a small set of basic emotions [Chan and Nejat 2010]. They are also being designed to be able to interpret users' affective states [Derek et al. 2012], so that they can adjust their behaviour accordingly. However, expressing and understanding emotions are challenging and achieving accuracy in such behaviours should be a long term goal, which becomes even more challenging when the users are older adults as fewer data sets and research have been done with this population. Additional challenges include, but are not limited to, detection of people's emotions, showing proper emotions, and understanding the communication strategies that would be suitable according to an individual's personality as these can differ from younger adults. As personality can shift with illness or chronic conditions, gaining a deeper understanding of how this affects communication and engagement is a key area of current research [Konig et al. 2018].

23.0.5.4 Agent Selection: Physically Embodied versus Virtual

Another challenge when developing an assistive agent for aging is to select the right platform. Usually there is a trade-off between the effectiveness of the platform and its cost. For example, a robot might be more effective due to its embodiment, however, it might not be affordable or practical for many of the intended users. It may also need more effort from the older adults to maintain it.

With the fast growth of technology, the platform should be flexible and allow upgrades and added features/assistive functions. It is not reasonable to expect that the older adults will frequently change the platform and adopt to new technologies. Ease of use in social robots has been reported as an important concern for caregivers as well [Pino et al. 2015].

When choosing the appropriate agent for aging assistance, the scientific evidence comparing the benefits of both virtual and physically embodied agents is still inconclusive. While robots have surpassed virtual agents performance in aspects such as supporting communication and collaboration through physical contact [Breazeal et al. 2016b] as well as motivating older adults to perform exercises [Fasola and Mataric 2011], similarly virtual agents have shown advantages in terms of pervasiveness, telecommunication, and emotional connection [Paiva et al. 2017]. Research has shown that physical agents have more authority over other types of agents (e.g., screen agents) and can be more persuasive [Li 2015b], so can be more suitable for applications where the robot has the role of a coach or therapist [Cabrita et al. 2018].

23.0.5.5 Long-term Adoption and Novelty Effect

Multiple reviews in the field of assistive and socially interactive agents in the context of aging have highlighted the need to conduct research over long periods of time [Pu et al. 2019, Whelan et al. 2018]. While the limited existing research has shown positive long-term effects of social robots in some contexts [Wada and Shibata 2007, Wada et al. 2005], most of this has only studied older adults' behaviours during a shorter period of time. Since the novelty effect tends to bias the responses of users in human-robot interaction scenarios when asked about attitudes towards technology, perceived usefulness, enjoyment, or ease of use [Smedegaard 2019], there is a growing need to consistently and longitudinally study the effects of socially interactive robots on older adults' acceptability.

23.0.5.6 Security and Privacy

Maintaining privacy is of utmost importance for technologies to be successfully adopted. The issue of privacy becomes even more challenging and important when designing technologies for older adults as many conditions (e.g., dementia) can affect users' perception and understanding of the security and privacy risks (thus assenting to the potential risks). Simple technology artifacts such as cameras can cause many ethical, moral, and practical concerns because not only end-users (i.e., older adults), but also caregivers and visitors may feel intimidated by the constant observation [Mulvenna et al. 2017]. Older adults' privacy concerns have included aspects such as who has access to footage, who watches the footage, where the footage is stored, and how secure it is [Mulvenna et al. 2017]. Therefore, while security risks should be minimized and the researchers should consider all the alternative options that can reduce privacy concerns (e.g., use voice recordings instead of cameras, if possible), it is also important to understand how to properly inform older adults about the possible security and privacy risks.

23.0.5.7 Enabling Choice

As with any user population, older adults value their autonomy and ability to choose. However, technologies for supporting older adults often do not support core and critical choices related to their use, such as when it is used, what it is used for, and who gets to make these choices. When they are available, these choices may not be presented to older adults in a way that they understand or reflect the factors they considered to be important in making related choices. A prominent example are technologies intended for supporting people living with dementia. These often require the person's caregiver/family to make choices about the customisation and use of the intervention with little or no ability for the person who is the targeted recipient of the technology (i.e., the person with dementia) to participate or make their own choices. While not all choices can be accommodated, it stands to reason that the people who are the users of the technology should have a voice in when and how it is used. Much of this can be achieved by developing technology in such a way that it conveys what it does and enables choice in a way that is appropriate for older adult users and that complements aspects they consider to be important.

23.0.5.8 Developing Policies

One possible approach towards reducing these challenges is to design policies for care centres and care of older adults around the use of assistive technologies in a way that supports their appropriate uptake and use. The technology usage policy in this context can focus on multiple aspects of design and adoption of the assistive agents for aging and could help with: (a) increasing privacy and addressing security and privacy concerns, (b) assisting older adults financially, by keeping the costs reasonable for the users (e.g., through government funded resources), and (c) improving older adults' trust and attitude towards technology. As the creators and experts, it is imperative that researchers and developers of technologies for supporting older adults share their knowledge and participate in the formation of such polices. This will help to ensure the creation of policies that guide appropriate and reasonable development and use of technology that also mitigate unnecessarily hindering it.

23.0.6 Future Directions

There is a need to create more personalized and custom-made applications of assistive agents targeting both healthy older adults and those with cognitive and/or physical impairments. The ultimate goal is to produce socially interactive agents capable of providing more adaptive assistance by using subjective, behavioral, contextual (e.g., surroundings and environment), and/or physiological data. Ideally, an intelligent agent should be able to combine information from many different data sources to provide truly personalized adjustments in real-time.

An important step towards creating successful assistive agents for supporting aging is to identify application areas where older adults are willing to use them. The literature to date is limited as definitive answers require studies with large and diverse groups of older adults. The application area can itself affect multiple decisions such as the type of agent (e.g., virtual agent, robot, etc.), agents' capabilities (e.g., technical aspects such as the type of sensors), and the necessary background for designing and implementing the agent (e.g., knowledge of specific areas of Machine Learning and Computer Vision). Researchers may have less flexibility with these design choices, due to limited resources such as the research team's background, availability of only specific virtual agents or robots in research groups, and costs associated with adding different functionalities to the technologies. Therefore, the current common approach is to select an application area based on the available resources in the team and to work with older adults to create an agent that would perform well in the selected application area. However, this might limit research to specific application areas and might not cover the application areas where older adults would highly benefit from an assistive agent. Further, older adults may not be interested in using social agents for specific activities for reasons such as trust or perceived impact on human relationships. Therefore, it is extremely important to work on identifying different application areas and understanding older adults' preference not only towards social agents, but also towards tasks/activities that these agents could help them with [Broadbent et al. 2009].

Another challenge that requires future work is making the assistive agents truly personalizable, with appropriate emotional and social intelligence. As discussed earlier in this chapter, such intelligence is highly beneficial for gaining older adults' trust and interest in using social agents. While emotional intelligence of technologies can be important in many domains, it can be key for adoption of socially interactive agents by older adults, especially for those with specific cognitive disabilities such as dementia [Konig et al. 2017]. Yet, there are many challenges involved in making them emotionally intelligent, including: (a) finding techniques and algorithms that allow us to properly understand users' emotions (which can be more challenging when the users are older adults), (b) understanding users' emotional states, and (c) adapting social agents' behaviours based on a users' personality. All of these challenges and more need to be addressed in the future work. Many of the existing models of emotions are inspired from how humans and animals show emotions, which can be informative for researchers to design computational models of emotions for agents [Breazeal et al. 2016a].

The next challenge that can highly affect the success of social agents for supporting aging is to emphasize their benefits in society and provide organizations with the financial and other resource support to acquire and use these agents. To that end, future research should work on developing policies that will facilitate adoption of socially interactive agents in care-home and the community as well as policies that accelerate their ethical design and use. These policies should be flexible enough to provide guidelines regarding the adoption of social agents running on different platforms and in different contexts.

Despite the general consensus that socially interactive agents should follow co-design processes, there are still limited guidelines about how to adjust the co-design sessions for older adults, especially for older adults with conditions such as dementia. Appropriate research methods need to be developed and disseminated in a way that the creators of social agents can understand and implement them consistently [Kachouie et al. 2014]. Older adult participants should be involved in activities beyond interviews, focus groups, and usability testing; they should be involved as active members of research and development teams who are able to provide rich information and aid data interpretation since they are living their own experiences with aging and technology and can convey these directly.

Finally, while there are many advancements in machine learning and computer vision, algorithms such as activity recognition, face recognition, voice recognition, detection of physiological states, and object recognition need to be improved to increase the accuracy and dependability of social agents. For example, datasets populated by older adults need to be assembled and used when recognizing voices, faces, and facial expressions, as they can differ from the available data used for training these algorithms, which consists primarily of data from younger adults. Improvements in these algorithms can enable researchers to create social agents that can act upon their environments and interact with older adults more appropriately.

23.0.7 Summary

The necessity of designing assistive agents that support aging is growing primarily due to the increasing population of older adults coupled with the increase in the abilities of assistive agents in improving older adults' quality of life and wellbeing.

This chapter began by discussing the need to provide more accessible and interactive assistive agents to support a fast growing population of older adults. We discussed how assistive agents can fill gaps caused by demographic shifts, help reduce costs, and improve older adults' quality of lives. This was followed by a an overview of the use of socially assistive agents (both virtual and physically embodied) to support aging. We then discussed different application areas and possible uses of social agents in those areas. Results to date have been promising, indicating that the assistive agents have good potential to improve different aspects of older adults' lives, including companionship, engagement, health, leisure, therapeutic, and ADL support.

Next, we presented different approaches for designing and developing assistive agents. Advantages, challenges, and considerations for older adults were discussed for five different methods (i.e., focus groups, interviews, questionnaires, ethnographic field studies, and case studies). We emphasized the importance of including older adults throughout the design process in order to create an assistive agent that can successfully be adopted by older adults.

The chapter also discussed considerations when designing agents to assist older adults. While many of the considerations are common with designing agents for other age groups and contexts, we argued that there are additional considerations when designing for older adults as different and changing physical and cognitive abilities need to be taken into account. We discussed some of the trade-offs for choosing a suitable platform for designing the assistive agents as well as the need to reduce the perceived complexity and the effort required to understand and use the technologies.

Existing challenges regarding design, development, testing, and deployment of assistive agents for aging were discussed, which covered: (a) developing technologies that increase older adults' acceptance of technology; (b) importance of ease of used and perceived need of agents; (c) increasing users' trust in the agents; (d) importance of agent selection between virtual and physically embodied agents; (e) long-term adoption and how to ensure that evaluations are not affected by the novelty effect; (f) improving security and reducing privacy issues; (g) supporting transparency and respecting older adults' choice, and (h) developing policies that support use of assistive agents for aging.

These challenges discussed in this chapter need to be addressed by the future work to aid the short and long term adoption of socially interactive agents by older adults. Areas that need to be addressed by future research include: (a) identifying application areas and gaps as perceived by the older adults; (b) revising existing methods to better involve older adults in the design processes; (c) improving accuracy of different aspects of the technologies (e.g., activity recognition, object detection, etc.); (d) improving the affective connection between the agents and older adults, (e) personalizing the behaviour of the agents according to the personality of each user; and (f) developing policies that will support the appropriate adoption and use of socially interactive agents.

This chapter provided concepts for researchers and designers to better understand considerations and challenges related to designing assistive agents for older adults, as well as ideas that can help with designing assistive socially interactive agents that can become successful in assisting older adults in many different aspects of their lives.

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