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# Shaping technologies for older adults with and without dementia: Reflections on ethics and preferences

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## Abstract

As a result of several years of European funding, progressive introduction of assistive technologies in our society has provided many researchers and companies with opportunities to develop new information and communication technologies aimed at overcoming the digital divide of those at a greater risk of being left behind, as can be the case with healthy older people and those developing cognitive decline and dementia. Moreover, in recent years, when considering how information and communication technologies have been integrated into older people's lives, and how technology has influenced these individuals, doubts remain regarding whether technologies really fulfil older users' needs and wishes and whether technologies developed specifically for older users necessarily protect and consider main ethical values. In this article, we address the relevance of privacy, vulnerability and preservation of autonomy as key factors when involving older individuals as target users for information and communication technology research and development. We provide explanatory examples on ethical issues involved in the particular case of developing different types of information and communication technology for older people (from robotics to serious games), what previously performed research tells us about older adults' preferences and wishes for information and communication technology and what steps should be taken into consideration in the near future.

## Keywords

assistive technologies, dementia, ethical issues, human factors, older adults, vulnerability

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## Introduction

As a result of several years of European funding, increasing introduction of information and communication technologies (ICTs) in our daily lives has provided many researchers and companies with opportunities to develop new devices and technologies aimed at overcoming the digital divide of those at a greater risk of being left behind, for example, older adults and people with disabilities.[1] However, it seems that technological advances and associated ethical considerations are far from running in parallel. According to Ienca et al.,[2] the vast majority of intelligent assistive technologies have been designed without considering explicitly the ethical values and considerations involved, which raises an alarm about the level of awareness of fundamental ethics principles by technology designers and the ethical sensitivity shown in current developments. In their view, Ienca et al.[2] state how issues like justice, equality, privacy and information security are frequently ignored, when device development should make them more affordable, safe and defensive of users' privacy, thus avoiding paternalistic approaches to end-users (i.e. ageism) and integrating values that may be relevant to end-users themselves.

Moreover, in recent years, significant lessons have been learnt about older adults' preferences about what they want and do not want from technology. When considering how ICTs have been integrated into older people's lives, and how technology has influenced these individuals, doubts remain regarding (1) whether technologies really fulfil older users' needs and wishes and (2) whether technologies developed specifically for older users necessarily protect and consider main ethical values. By way of example, Diaz-Orueta et al.[3] found that, when it comes to the integration of new ICT in their lives, older adults (1) do not want to depend on others but to have control of their lives and thus of their own technological devices;[4,5] (2) reject ICTs that increase dependency (concordant with the idea of preservation of autonomy, as described by many authors[6,7]) and (3) prefer existing devices that have been enhanced with new functionalities rather than learning how to use new devices or technologies (optimization of resources and costs).

In addition, with regard to the ethical values and considerations for involving older individuals in ICT-related research projects and product development, the issue of vulnerability needs to be addressed. According to Paragraph 9 of the Declaration of Helsinki,[8] 'some research populations are particularly vulnerable and need special protection. Those include those who cannot give or refuse consent for themselves and those who may be vulnerable to coercion or undue influence'. While it could be biased and paternalistic to consider the whole population of older adults as potentially vulnerable, the fact that the current cohort of older individuals aged above 65 years have only relatively recently been exposed to an era of constant technological development and change may raise concerns about the exclusion and lack of access to services for those late-adopters who may be left behind when adapting their daily life to integrate the latest technological developments. This has been a concern increasingly addressed by the European Commission through funding programmes such as FP6, FP7 and H2020, and it is a concern significantly more evident in the case of those older individuals who develop any kind of neurodegenerative disease such as dementia. Decline in cognition (e.g. in functions like memory and higher executive functions such as abstract reasoning, planning, decision-making, problem solving and judgement) is an early indicator of an underlying neurodegenerative process.[9] When a decline of this nature takes place, the role of ICTs can either be a supportive tool or, in contrast, an agent for a larger decline. According to Sanchez,[10] the main challenge and difficulty to overcome concerning technology designed for people with cognitive disabilities is the preservation of personal autonomy, since there is a thin line between improving and limiting individuals' lives, as opposed to compromising their privacy and freedom given the potential to overlook their dignity and integrity. Consistent with Van Hoof et al.,[11] a simple instruction list for the development of technologies for people with cognitive decline and dementia should include ICT that (1) minimizes new learning, (2) looks familiar, (3) does not take control away from the user and (4) keeps user interaction to a minimum (unless supporting user interaction is the goal of this technology).

With these preliminary ideas in mind, in this article, we address the relevance of vulnerability as a key factor when involving older individuals as target users for ICT research and development. We will provide explanatory examples on ethical issues involved in the particular case of developing different types of ICT for older people (from robotics to serious games), what literature tells us about older adults' preferences and wishes for ICT and what research in this area should take into consideration in the near future.

## Vulnerability: definitions and types

The US National Bioethics Advisory Commission (NBAC[12]) describes vulnerable participants as those persons who may have difficulty providing voluntary informed consent, resulting from limitations in decision-making capacity or situational circumstances that put them especially at risk for exploitation. Individuals may be vulnerable to or victims of physical control (i.e. physically forced to participate in research), coercion (use of a credible threat of harm or force to control another person), undue influence (the misuse of a position of confidence or power to lead or influence others to make a decision they would not otherwise make) or manipulation (lying, withholding information, exaggerating and so on to lead subjects to make a decision they would not otherwise make). Furthermore, the NBAC[12] defines the following as the potential types of vulnerability:

- *Cognitive vulnerability*: this is the inability to comprehend information, deliberate and make decisions about participation in a proposed research study. This could be due to lack of capacity to make informed choices (e.g. adults with cognitive impairments that affect decision-making), situational cognitive vulnerability (e.g. persons during a medical emergency situation) or communication problems (i.e. not reading or speaking the same language as researchers, speech difficulties, low educational level or illiteracy, etc.). As Ienca et al.[13] point out, when recruiting participants with cognitive vulnerability for research, researchers must guarantee that potential subjects agree to participate in research freely and willingly after having been extensively informed about the research process and that they have demonstrated a clear understanding of such information and satisfactory responses to possible questions, without undue influence from third parties (which may include informal caregivers).
- *Institutional vulnerability*: this may be experienced by those who are subject to the formal authority of others. Individuals may have the cognitive capacity to consent to participate but may be unduly influenced (or coerced) in doing so, and they may be subject to exploitation because of their subordinate status.
- *Deferential vulnerability*: this is similar to institutional vulnerability, but rather than being based on official hierarchy, the power relationship may be based on gender, race, class inequalities, inequalities in knowledge (i.e. doctor-patient relationship) or other inequities (e.g. patient–caregiver relationship).
- *Medical vulnerability*: this arises when prospective research participants have problems differentiating between research and treatment, because of their own serious health condition (e.g. severe health issues or terminal illness). As a result, individuals may overestimate potential benefits in a context where they are limited in their ability to process information, make complex decisions and communicate their desires, thus affecting their autonomy. In the particular case of terminally ill patients, the desire to please their caregivers can alter their decision, since risks and benefits are not weighed in the same way.

- *Economic vulnerability*: when prospective research participants are underprivileged in the supply of social goods and services, participating in research may offer them the possibility of payment or attainment of healthcare or other services not otherwise available. This threatens the voluntary nature of consent and raises the danger of exploitation.
- *Social vulnerability*: prospective research participants who belong to undervalued social groups, who are perceived as less valuable to society (according to the researcher), could lead to reduced concern (by researchers) for risks and burdens and increase the risk of exploitation for these groups (e.g. African American population during the first half of the 20th century, Jewish people in Nazi Germany, etc.).

## Older adults with and without cognitive vulnerability: factors affecting ICT adoption

According to Fischer et al.,[14] although there are differences in how older adults approach ICTs, both older adults and their relatives are increasingly using technology to improve both their healthcare and lifestyle. However, different barriers both for technology adoption and acceptance may be faced by them, including issues related to technology familiarity, willingness to ask for help, trust of the technology, privacy and design challenges (such as sensory problems – sight and hearing loss – or cognitive, navigation and memory issues) all of which may make technology a major challenge to learn and use.[15]

In the particular case of people living with dementia, Bennett et al.[16] depict a more complex scenario, as they point to a lack of proper analysis in terms of how ICT could support the human rights of these individuals. In their own view, although assistive technologies may support independence, some technologies have the potential to intrude upon the rights, privacy and freedom of people living with dementia. According to Diaz-Orueta and Urdaneta,[17] this implies that individuals with cognitive decline and dementia need proper information when they are faced with the introduction of new technologies in their daily-life settings, as the final decision in relation to this technology insertion should be theirs. Even in the case of conflicts between people with dementia and their caregivers' desires and opinions, the ultimate decision from the end target user of that technology has to be respected as long as the individual is still capable to decide reasonably on issues affecting their daily life.[18] Doyle et al.[15] remark that older adults experiencing cognitive decline may have a significantly larger learning curve, with higher difficulties and more time required to learn new skills, compared with younger adults or, in some cases, with those without cognitive decline. Moreover, physical impairments related to sensory loss, affecting visual, auditory and tactile capabilities, exacerbated in neurodegenerative conditions, may further distance older adults from the assistive support of technology.

In the case of older adults with cognitive decline, with or without a formal diagnosis, who are still competent (understood as the ability to make coherent decisions that affect themselves or others), they remain responsible for deciding on any issue affecting any domain of their daily activities. However, problems may rise with the definition of the term 'competence', which may comprise multiple meanings: 'ability', 'capacity' and so on.[19] The primary distinction is widely used in forensic settings, so it is essentially legal, and law requires that incompetence must be proved while presuming that all adults are competent to make treatment decisions unless there is evidence for the opposite. Nevertheless, as pointed by Rivera-Mindt,[19] questions about competence are routine in many circumstances, and competence is a 'context-dependent' construct, which means that impaired decision-making in one area does not necessarily imply lack of competence in other areas. As stated by Marson et al.,[20] people with mild Alzheimer disease can show preserved decision-making skills and essentially no difference to cognitively intact individuals in terms of their likelihood of assenting. In addition, they preserve the ability to express choice and in doing so appreciate outcomes and consequences and provide reasons that demonstrate a rational thinking process.

From a more positive perspective, authors such as Ienca et al.[13] and Kim et al.[21] defend the idea of development of intelligent ICTs for physical, cognitive and behavioural support, as well as for facilitated care delivery and monitoring. These ICT could help older adults with a neurodegenerative disease to either continue living independently in their own homes or to maintain their independence in healthcare facilities, with what has been called the 'triple-win effect' on dementia care provision:[16] (1) delaying the need for institutional care, which reduces healthcare costs associated with long-term chronic care and institutionalization, (2) reducing the caregiving burden on informal caregivers and (3) enhancing individuals' quality of life by improving their independence, autonomy and social interaction and by helping to fulfil their wish to age in place.

What should then be taken into account to overcome these potential barriers? Robillard et al.[22] outlined the following as facilitators for adopting new technologies: (1) perception of convenience and possible benefits, (2) usability (perception of user friendliness and ease of learning), (3) affordability (perception of potential cost savings), (4) accessibility and availability in the market, (5) technical support availability and quality, (6) social support from relatives, friends, peers and community, (7) perception of emotional and psychological benefits, (8) perceptions regarding how technology makes someone look to others, (9) relevance to previous experience and interactions and (10) confidence to use technology without anxiety or intimidation. Previously, Wu et al.[23] suggested that the specific development of gerontechnologies directed to older adults may encompass a stigmatizing symbolism that can stop them from adopting these technologies. In their study, older participants perceived the existence of a digital divide caused by generation/cohort effects, age-related physical and cognitive decline and resistant attitudes towards technology. Nonetheless, while older adults reported increasingly adopting different types of commonly used ICTs in everyday society, the specific development of assistive ICTs and the so-called gerontechnologies had very negative images for them, and they expressed an associated lack of perceived need and usefulness.

Peek et al.[24] identified technology acceptance as being influenced by 27 different factors grouped in six themes, three of which were basic human factors such as available alternatives to technology (help and support of other family members), social influence from family, friends and professional caregivers leading (or not) to technology adoption and the desire to age in place. At this point, feeling part of the same society as others and not being treated differently because of their age is an obvious key factor for technology acceptance by older adults (which also implies that technology should be normalized, instead of talking about 'gerontechnology'). Currie et al.[25] stated that as long as technological support is not seen as a replacement to in-person, face-to-face care, the chances for acceptance are higher. For example, technological health solutions in the home of an older person living alone may provide reassurance to the individual, relatives and friends and can constitute a cost-effective way of enabling the individual to remain living independently. Still, if such a device implies a reduction of visits by health professionals, could the well-being of the individual suffer from a drastic decrease in the opportunities for social interaction with and appropriate interventions by professional healthcare staff? As Currie et al.[25] admit, the lack of standardized measures to determine what the most appropriate combination of eHealth and other types of care would be is a question to be solved.

In an attempt to progress the prediction of factors for technology acceptance by older adults, Golant[26] developed a model that predicts if older adults will evaluate positively the inclusion of technology to help them cope with daily living. The model proposes that older individuals differentiate three attributes of their coping options when they make their judgements: perceived efficaciousness (usefulness, relative advantage), perceived usability (effort expectancy) and perceived collateral damages (unintended harm). The model claims that the more positively older people evaluate their coping options, the more likely they will adopt them, that is, engage in one of the following three assimilative or action-oriented coping processes: (1) adopt one or more smart technology coping solutions, (2) adopt one or more traditional coping solutions and (3) adopt some combination of smart technology and traditional coping solutions. Nevertheless, some older individuals will not become involved in assimilative coping processes but will instead depend upon cognitive strategies by which they deny or rationalize their problems to make them 'disappear'. As a consequence, they can cope in an alternative way in that they take no concrete steps or actions and engage in adaptive mind or accommodative coping strategies. Based on this model, Golant[26] outlines a series of action strategies that would increase older adults' openness to new technological devices and solutions:

1. To identify unmet needs that are most likely to motivate technology use by older individuals;
2. To offer educational and public service programmes that increase the resilience of older people and thereby make them less fearful of new technological solutions;
3. To ensure that older people can take proper advantage of credible information about smart technology solutions;
4. To offer more compelling information that demonstrates the utility and usability of smart technology solutions;
5. To identify external information sources that may influence how older adults assess ICT solutions;
6. To better understand older adults' earlier experiences that both encourage and constrain their current technology adoption attitudes and behaviours;
7. To make older adults' fears about potential damages from technology disappear;
8. To demonstrate that ICTs can produce better health and care outcomes than traditional coping solutions;
9. To understand better why some older adults will be more resistant and decide to cope with their problems by using accommodative strategies;
10. To make smart technology options more affordable to both lower- and middle-income older adults, which means design and development of specific policies in this regard.

## Older adults and ageing in place: the role of autonomy and environmental control

Enabling older adults to stay in their own home as long as possible (i.e. to age in place) has become a major concern in developed countries for societal and economical motivations (improving well-being and autonomy, care and assistance). As Bouakaz et al.[27] state, the challenge that our society must address is to enable older adults to age in place as autonomously and safely as possible while relieving some of the burden supported by the carers. Indeed across studies, 'autonomy' preservation is emerging as the key factor from all of the ethical issues and principles involved in research about ageing in place. Autonomy can be defined as the ability and exercise of taking one's own decisions in whatever affects daily life.[19]

As discussed by Estrada-Hernandez and Bahr,[28] autonomy interrelates with both self-determination and decision-making, and with regard to this, the person needs to have clear information related to when, what and how ICT will be used to preserve their sense of autonomy, which in the case of individuals with disabilities may limit their ability to consent. As dementia has a significant impact on a person's autonomy, any technology developed for these vulnerable individuals should preserve their autonomy as long as possible, constituting a support rather than a substitution of one's own performance that may constrain and reduce the repertoire of behaviours that people with dementia are still able (and willing) to do by themselves. Hughes et al.[29] created a set of recommendations for caregivers (and for anyone supporting people with dementia) including the following: avoid treating the individual as a child; communicate all that is important and relevant; obtain informed consent for every procedure requiring the individuals' participation; avoid talking about the individual with dementia in front of them as if they are not present; and overall, recognize and validate the individual as the person they are.

In relation to autonomy preservation, environmental control also demands some attention. The individual's sense of having control over the environment where they live (over decisions involving their home, decoration of their room, raising vegetables on a small piece of land, caring for a plant or a pet, etc.) has been defined as a key variable for longevity (when preserved) or as a mortality predictor (if removed). Research on how older adults who keep control over their environment and how it is set up[30–32] shows a higher maintenance of cognition, mood and longevity. A sense of control implies the perception that individuals can influence what happens in their own lives and to what extent their behaviours can bring their desired outcomes. It comprises beliefs or expectations about one's own abilities and perceptions about external constraints. As precisely described by Agrigoroaei and Lachman,[33] a decrease in perception of control may imply a series of affective, motivational, behavioural and even physiological consequences, including higher levels of anxiety and stress, lower levels of effort, persistence and strategy use and reduced involvement in cognitively demanding tasks, that can have an impact on the individual's cognitive fitness and performance. Technologies supporting older individuals at home should enable the person to keep track of their own tasks while they desire and are still capable of doing these tasks by themselves.[17] If ICTs aim to support daily activities, they should provide the minimum support that is necessary for the person to keep control of their daily environment (both for basic and instrumental activities), since a reduction of environmental control may increase excess disability which accelerates decline, reduces autonomy and eventually hastens mortality.[34]

The following sections will focus on how different types of technological developments have evolved for older adults in the areas of robotics, serious games, virtual reality (VR) and augmented reality (AR) and whether and how ethical issues such as privacy, vulnerability and preservation of autonomy have been properly addressed.

## Older adults and robotics

The development of prototype robots to provide support for independent living of older adults even in cases of functional decline has been prolific in the latest 15 years. Many personal service robots have been developed, including Aibo,[35] Care-O-bot,[36,37] Hobbit,[38] iCat,[39] Pearl,[40] Robocare[41] and Robot-Era robots.[42] Other robots, such as Companionable,[43] Giraff,[44] GiraffPlus,[45] Huggable,[46] MARIO[47–49] and Paro,[50] have been developed to provide the individual with emotional support and for other companionship purposes. In this framework, different researchers have discussed the optimal type of companionship that robots could deliver.[51,52] Nevertheless, as García-Soler et al.[53] highlight, the impact of the inclusion of robots in the daily lives of frail older adults in terms of meeting individual requirements and needs and the relationship between the ethical implications and possibilities of these technologies was not properly examined until recently.[54–56] As a result, García-Soler et al.[53] attempted to devise a step-by-step procedure to identify and prioritize user requirements for robotic technologies. Results showed that older participants were more interested in having an electronic device that would provide support in tasks that they could no longer perform autonomously rather than having a smart interactive robotic machine. Using a multiple qualitative strategy involving individual interviews, testing scenarios, focus groups and an ethnographic approach, they showed that the main requirements for a sample of frail older adults in their potential interaction with robots as home companions was to get broad support with physical tasks: for example, support with instrumental activities of daily living, especially with sequential tasks and housework (i.e. carrying heavy objects, cooking), basic activities of daily living (i.e. getting up, reaching things, etc.), cognitive support (i.e. arranging and reminding appointments, medication reminders), emergency monitoring, social interaction and communication with others (preferring human to robotic interaction), ensuring privacy is respected, safety in the caring process and suitability of the robot to the environment (robot–environment interaction), with consideration of the fact that users' needs are dynamic and can change over time.

While many studies support the idea of a preference for human-versus-robotic interaction, De Graaf[57] expressed the concern that the human–robot relationship may replace their human counterpart in social relations and predicted that if people share feelings with robotic others, they may become accustomed to the reduced emotional range that these machines can offer.

This raises concerns about the main ethical issues that need to be considered when developing robot companions for older adults. Körtner[58] argues that the ethical concerns are similar to those observed with other assistive technologies: potential loss of autonomy, privacy, data protection, safety, prevention of isolation, overstressing of users and so on, all of which leave older adults in a position of vulnerability with regards to the adoption of proper, fully informed decisions on whether they should (and if so, how to) integrate robotic solutions in their daily lives. In addition, a regulatory legal framework for the relationships between humans and robots is required, as different types of robots might evoke different requirements and considerations based on their functional design and the setting in which they are used. Finally, Körtner[58] points out that ethical considerations in robotics for older adults should not only ask what view we have on technology but also what image of humanity prevails in robotics. Vallor, as cited by Sorell and Draper,[56] identified a series of tensions and problems between the design and use of carebots and the morally desirable treatment of older persons as autonomous adults: the objectification of the older adults as 'problems' to be solved by technological means and the potential for carebots to either enhance or restrict and reduce (1) the capabilities, freedom, autonomy and/or dignity of cared-fors, (2) their engagement with their surroundings, (3) their privacy and (4) levels of human contact with families and other human caregivers.

## Older adults, serious games technologies and VR

Digital games may satisfy diverse needs of older adults.[59] Adults play digital games for many reasons, and these vary according to previous exposure to games and cognitive and physical abilities. Zonneveld and Loos[60] found that playing a fitness exergame served not just as therapeutic task, improving physical and social well-being, but also provided entertainment, excitement and fun as reported by the participants of the study. It has been suggested that older people prefer games with a purpose or value, providing educational or cultural benefit and cultivating the sharing of knowledge.[61] In other words, the social possibilities of games seem to be a key factor regarding older adults' motivations to play digital games. Experienced older gamers are social, community-oriented gamers, and special emphasis is placed on social contacts, mutual help during the game, sharing games objectives, chatting about everyday topics during the game sessions and/or being connected to one's significant other.[62–64] In relation to social play, older people seem to prefer co-located play (in the same room) above social play over the Internet (i.e. mediated play). An experimental study by Gajadhar et al.[65] found that older adults' player experience during social play was most positive in co-located play and solo play, whereas the least enjoyment was experienced in mediated play without means for face-to-face interaction. In a study performed by Diaz-Orueta et al.,[61] as part of the European-funded LEAGE project, the key factors for older adults' willingness to play videogames were challenge (as a basic foundation for the game development) and socialization. Participants clearly stated that they wanted to play with, not necessarily against, others and they wanted the games to provide learning opportunities and escapism from routine daily life. Nap et al.[66] describe in more detail how specific lifetime experiences, world knowledge, age-related changes in perception, cognition and motor control are likely to have an influence on specific gaming preferences, motivations and needs, even though it is possible that overlap exists between the motivations of younger and older adults to play digital games. Due to functional changes and a lack of technological experience, Nap et al.[66] state that older adults are affected significantly more by usability problems than younger users.

While many serious games have addressed psychological interventions for children and younger adults, development of serious games is scarce for healthy-ageing older adults and for those undergoing a neurodegenerative process in the brain.[67] In many cases, as stated by McCallum and Boletsis,[68] there are no dementia-specific serious games but a re-orientation of games previously designed for entertainment that are now being used to target cognitive function in people with dementia. Whether the effect of those games is long lasting or transferable to players' daily life must be determined in future studies.

Complementary to serious game interventions, VR may add value to traditional psychological intervention by providing users with safe environments for training and skills acquisition (e.g. learning of coping skills to deal with phobias, fear, anxiety, etc.) and reproducing realistic environments for treatment that should otherwise be faced by the person in potentially less safe and effective but more 'traditional' ways.[69] Although there has been intensive work in recent years regarding VR cognitive rehabilitation tools, in particular by Parsons and Rizzo,[70] there are no specific VR intervention programmes focused on older people, either healthy or with neurodegenerative conditions. This is a significant gap especially in terms of ecologically valid interventions for maintenance of cognitive fitness; some studies[71,72] do address the advantages relating to cognitive rehabilitation.

Given that developments in the area of serious games and VR applications for older adults have been infrequent, research on how these types of ICT approaches may affect older adults' is also scarce. To our knowledge, only one recent study by Siriaraya et al.[73] discussed the benefits of virtual environments for older adults and found that virtual worlds could help them in four main areas: (1) alleviate the effects of age-related diseases and disabilities, (2) facilitate social engagement and expand their interpersonal relationships and social network, (3) perform productive activities inside the virtual worlds without the limitations of physical conditions or age (including paid work in virtual worlds) and (4) provide mental stimulation. The next section will approach the very new area of AR and the main developments involving older adults and their needs and preferences.

## Older adults and AR: what we know so far

As described by Weerasinghe et al.,[74] AR technology has the potential to mix virtual and real objects, thus allowing the individual to experience mixed content in various dimensions such as temporal, spatial and contextual. It consists of the superimposition of some animation or image in a realistic way, over an imaged captured by a digital camera,[75] and it has multiple applications for visualization of complex structures, educational games or design-based learning, among others. According to Baker et al.,[76] immersive technologies like AR can provide an opportunity for older adults to experience or relive social experiences and activities, and they can create a sense of presence or awareness by having the person using their own body to interact with others through body orientation, gestures and facial expressions.

In terms of the usability and acceptance of AR by older adults, mixed results have been presented so far. Haesner et al.,[77] for example, tried to evaluate the suitability of the Google Glass device for older adults, and the main concern raised was not the fear of privacy loss or the lack of data security but the fear of falling when walking with the device, yet reports are mixed regarding the distracting and intrusive nature of wearable devices like Google Glass. In studies using AR to assist older drivers, AR cues were not distracting and even improved older users' performance with gap estimations for turns[78] and with detection of hazardous target objects[79] compared with drivers not using AR-based cues. Peleg-Adler et al.[80] developed an AR-based route planning task of public transportation and tested older adults using both a handheld see-through AR interface and a standard non-AR application on a mobile phone. AR see-through technology appeared to be intuitive, easily adopted and enjoyable for older adults. According to these authors, AR has the potential to be adopted by older adults and be more easily accepted than other solutions.

Some studies have shown the potential of AR for the improvement of spatial visualization abilities in older adults, by allowing them to directly manipulate virtual three-dimensional models of cubes to improve mental rotation abilities,[81] and thus negating the need to translate from a two-dimensional flat image.[82] Separately, Ahn et al.[83] developed an AR-assisted mobile grocery-shopping application to make real-time, customized recommendations of healthy products to users and mark products to avoid food allergies and high sodium and high caloric foods, depending on each individuals' preferences and needs. They found that their application reduced the search time to find healthy food items and that colouring the tags helped to improve users' ability to quickly and easily identify recommended products, as well as products to avoid.

In terms of games using AR technologies, Weerasinghe et al.[74] showed that the use of AR games can be applied in any indoor or outdoor learning environment and that it enhances active and authentic learning and creates an opportunity for an enhanced student-centred learning. As an example, Khoo et al.[84] developed an AR game called Age Invaders by using a LED floor display not affected by shadows or players moving on the platform, providing the older adults a wearable-free game that allowed them to use their whole body as the interface.

There has been more AR development with older adults in the area of motor rehabilitation and falls prevention. Lo Bianco et al.[85] developed an iPad-based AR environmental visualization application prototype for discussion and evaluation of falls risk with health professionals, and it allowed them to perform home modifications that would improve fall prevention. Haarman et al.[86] tried to develop a visuomotor walking task in an AR training setting, but they did not succeed in showing improvement of walking abilities, which they attributed to the difficulty of the task and the suboptimal feedback presentation used in the training setup. In contrast, Yoo et al.[87] showed that older adults using the AR-based Otago exercise system improved their balance and reduced their risk of falls. In their view, AR-based treatment environments increase task complication gradually and help to increase the effects of the education. According to Im et al.,[88] using AR exercise systems can augment postural control in older adults by stimulating the sensory processes responsible for maintaining balance and orientation, and they found that their AR exercise system could enhance lower extremity function in older adults.

With regard to technologies involved in AR application, Weerasinghe et al.[74] identify an evolvement from handheld devices to head-mounted displays and holographic projections. With regard to this, the Coach Assistant via Projected Tangible Interface (CAPTAIN) H2020–funded project (www.captain-eu.org) will develop a radically new human–computer interface that uses micro-projectors and projected AR to provide assistance whenever and wherever it is needed. As described by Hopper et al.,[89] CAPTAIN technology utilizes smart home appliances to turn a room into a tangible, interactive and user-friendly interface capable of capturing relevant physiological, behavioural and user interactions through unobtrusive means. CAPTAIN will also provide cognitive and physical training through serious games to increase engagement levels and a motivational coach that provides personalized guidance designed to enhance an individual's engagement in cognitive activity, social interaction and healthy nutritional and exercise habits. Here, the main ethical concerns of privacy, vulnerability and preservation of autonomy will need to properly be addressed.

As it can be seen from previous examples, AR can play an important role in assisted living for older adults, as it offers automatic context detection and realistic introduction of information into the environment, enabling autonomous interaction for older adults. Saracchini et al.[75] even indicate that AR can be a tool for personal development. However, fears and concerns towards technology in general also impact AR-based development. Baker et al.[76] state that a common concern about AR is that it may result in further isolation for older adults if it replaces human care. As Schlomann et al.[90] indicate, fears about data loss, misuse of data or the threat of cybercrimes are among the primary reasons for older adults' non-use of ICT apps or devices. In the development of AR applications, transparency of information regarding what data is collected and for what purposes is essential and personal support in terms of tutorials or training videos for AR-based applications would be essential.

## Future research in ICT for older adults: an attempt to conclude on general recommendations

This literature review has shown that unequal levels of research exist regarding environmental control, robotics, serious games, VR and AR. Trying to send a unified message that covers common recommendations for all these areas is a very difficult task; indeed, some areas need to make progress regarding the inclusion of older and other vulnerable populations while they consider thoroughly the ethical dilemmas they may encounter.

However, we consider that some common ground can be established for all the research areas addressed. In terms of recommendations for improvement, we suggest that technology should be oriented less to pure safety and risk avoidance and instead should focus more on the preservation of autonomy and dignity of older adults as human beings, regardless of their cognitive status. The line between a safe living environment and a jail at home (i.e. a home environment that either maintains or revokes the older individual's dignity and autonomy) is very thin and a source of controversy. Thus, the establishment of general guidelines for ICT involvement of vulnerable populations, such as older adults with and without cognitive impairment, is a difficult duty that leads to new questions and dilemmas.

Regardless of the specific area of research (be it robotics, videogames, VR/AR or other technologies to come), researchers and developers need to do their 'homework' now and in the immediate future in terms of (1) increasing their knowledge on ethical and regulatory aspects of the country in which they live and develop their work, (2) increasing their experience in dealing with and supporting older people and, most importantly, (3) keeping an ethical but 'common sense' approach based on treating others as human individuals regardless of their age. The studies reviewed here highlight a lack of awareness and knowledge about ethical considerations, ethical dilemmas and ethical principles associated to both clinical and research work with vulnerable populations. As Estrada-Hernandez and Bahr[28] recently found, ethics training and increased awareness of circumstances that can develop into a potentially harmful situation for the person receiving services is essential. From their data, 20 per cent of the overall sample of AT professionals surveyed indicated that they have never experienced an ethical dilemma (which may relate to the broad definition or lack of clarity of what constitutes an ethical dilemma), and participants were both less likely and felt less confident in addressing potential ethical dilemmas related to client/patient issues. This lack of knowledge about ethical dilemmas and implications was also recently reported by Hall et al.[91] who illustrated that surveillance of staff in care homes for people with dementia was not considered to have any ethical implications, any concerns about remote monitoring of staff were considered in terms of utility of the recordings (i.e. to show evidence of appropriate care by staff rather than in terms of ethical considerations of staff discomfort) and when any objection was made to the use of surveillance technologies, these were mainly made in relation to the potential impact or discomfort upon residents rather than upon the staff. However, Denecke et al.[92] emphasize the need for an increased awareness of ethical issues involved in patient–physician relationships, the preservation of confidence and privacy and the preservation of patients' anonymity when using online healthcare applications, for the sake of both good medical practice and the future of medical research.

Finally, the normalization of assistive technology throughout the life cycle is essential; since we all become more used to using technology to support our daily lives, the idea of doing so once older and/or diagnosed with a particular health condition should be less off-putting. Also, there is a need to remember that the older adult, even with dementia, is still a person and has the ultimate choice when faced with decision-making about their daily life and environment. However, the ethical approach to technologies developed for older adults, as Ienca et al.[2] remark, cannot be merely reactive and those experts in ethics involved in this type of research and development have a parallel obligation to be proactive in addressing ethical challenges inherent in these technologies. In other words, instead of performing an ethical analysis solely on technologies once they are developed, those with ethics expertise should have a proactive attitude and cooperate with designers and developers in the responsible creation of new, ethically sustainable products, especially, since an ethically designed successful technology greatly increases the prospect of improving the lives of older adults, people with dementia and their families.

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