Robotic and virtual reality technologies for children with disabilities and older adults

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Abstract. Robotic and virtual reality technologies have been used with children with disabilities and older adults for different purposes. In this article, after summarising the characteristics of these technologies and listing various applications, we discuss the different challenges of developing them for children with disabilities and older adults, even if the intervention goals are similar. This sets the context for the articles addressing some of the identified challenges that were submitted to a special thematic session on robotic and virtual reality technologies for children with disabilities and older adults held at the ICCHP-AAATE 2022 conference.

Keywords: Human-Robot Interaction; Assistive Robots; Virtual Reality; Children with Disabilities; Inclusive Education; Older Adults

1 Introduction

In the last few decades, there has been a significant interest in the use of robotic and virtual reality technologies with children with disabilities and older adults.

Robots are programmable mechanisms that move within a physical environment exhibiting a degree of autonomy. Its physical presence enables them to act upon the environment and to interact with people directly. Being programmable, capable of sensing the environment and of exhibiting different degrees of autonomy, robots can be used for different goals and adapt their behaviour in response to the environment and/or to the person they are interacting with. Robotic systems may also be a valuable tool in objectively assessing educational or therapeutic goals by registering all variables of interest during interventions. These features have motivated the development of robotic tools to assist children with disabilities and older adults [1–3]. Applications include the use of robots in a) inclusive education [4], allowing children to actively participate in the curricular activities (robotic assistive technologies to support manipulation), providing a direct application medium for the theoretical concepts under study (educational robotics), or interacting with children to support their learning (social robots acting as teachers or peers); b) cognitive therapy/training [5–7] (social robots that foster cognitive skills and language development); c) physical therapy/activity [8, 9] (robots designed to engage children and older adults in physical therapy/activity); d) stress and pain management [10–12] (social robots acting as companions of children or older adults with a chronic illness or undergoing medical and/or mental care); and e) promoting play for the sake of play [13, 14] (robots being the play object or providing a means to access to play).

Virtual reality (VR) environments are those in which a person "is totally immersed in, and able to interact with, a completely synthetic world" [15]. These lie in one extreme of the "virtuality continuum" [15], with real environments on the other extreme. In the middle are those environments mixing real (physical) and virtual (simulated) objects. Examples, from the real environments to the virtual reality environments extremes, are a) augmented reality, when virtual objects are overlaid on a view of the real environment; b) mixed reality, when real and virtual objects coexist and the user can interact with both; and c) augmented virtuality, when real objects are represented in a virtual environment. The term extended reality has been used to encompass all different combinations of real and virtual environments [16]. Extended reality systems allow for the involvement of persons in realistic virtual situations, substituting real-world experiences. That may be desirable, for example, when real-world experiences can put someone at risk (e.g., piloting a plane or performing a surgery), or are very difficult to replicate (e.g., walking on the Moon's surface). Virtual environments have also the potential of being more engaging to people, since they can be designed according to the user preferences. The main driver for extended reality systems has been the gaming industry, but many applications have been developed for children with disabilities and older adults [16–19]. Areas of intervention greatly overlap with the ones in which robots are being used, namely a) education [20], building augmented reality scenarios that enhance the learning experience or making available simulation scenarios for training skills; b) cognitive therapy/training [21] (virtual reality activities to train attention, memory, spatial orientation, social or communication skills); c) physical therapy/activity [22] (engaging serious games to increase adherence to physical exercises); d) stress and pain management [23, 24] (VR applications to divert attention from painful procedures or to help dealing with anxiety); e) promoting play for the sake of play [25].

Even though robotic and virtual reality technologies have been used with the two extremes of the age continuum, sometimes with similar goals, challenges in developing them for children and for older adults are different and reviewed in the following sections.

The references included in this introduction contain general literature reviews on the topics addressed in sections 2 and 3. For a list of references specific to each robotic application, please refer to: https://sites.google.com/view/robots4children/useful-references. Section 4 briefly summarises the articles submitted to the special thematic session on robotic and virtual reality technologies for children with disabilities and older adults held at the ICCHP-AAATE 2022 conference.[1]

2 Challenges in developing robotic and VR technologies for children with disabilities

Advancements in robotics are determining important changes in the lives of children with disabilities. Most notably, with the advent of intelligent technologies capable of engaging people in social interactions, children can not only interact *through* technologies but also *with* technologies. In this view, over the last decade, research on robotics and other emerging technologies for children with disabilities has taken an important place in the development of more effective healthcare and educational intervention.

With reference to applying robots in healthcare settings, for instance, one of the most promising and researched application domains of socially assistive robots (SARs) is as support in treatment interventions for children with neurodevelopmental disorders. Most research in this application domain has been carried out with children with autism spectrum disorder (ASD) to foster the development of their social and communication skills. Physical rehabilitation is another area of intervention in which robotic technologies such as exoskeletons have been successfully applied (e.g., to reduce motor disability associated to cerebral palsy). In this rehabilitation context, interactive technologies such as those involving sensors linked to computer, immersive, or virtual reality systems can be employed in combination with exoskeletons to facilitate the child's engagement in a pleasant and motivating manner and, to a large extent, independent of staff direct and consistent guidance.

Despite the encouraging results from the application of robot-based activities in healthcare settings for treatment and rehabilitation, it should be recognized that research in these areas is still in its infancy. More evidence is needed, for instance, on the effectiveness of robot-based intervention protocols, as well as on demonstrating outcomes transferability from one context to another. In addition, the use of socially assistive robots in therapeutic/educational interventions for ASD has been recently criticized on the ground of ethical considerations. For example, it has been highlighted the risk of reducing human contact for children with ASD when using a SAR in therapy as well as educational sessions. Another critic is that there is no evidence that all children with ASD are attracted by artificial agents. To overcome such challenges, user-centred co-design methods should be followed, in which therapists, parents, children and other key stakeholders should play a central role in developing scenarios where robots may be useful tools in achieving child-centred goals.

With reference to applying robots in education, social robots have been shown to promote more learning gains and to evoke more expression of emotion through the

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creation of personalized learning ecosystems when compared to screen-based technologies such as tablets. In these educational contexts, social robots may take on a variety of different roles, including that of tutors or peers.

Translating evidence into real educational practice, however, is challenging due to the lack of accessible indications and best practice examples on how teachers can use robots in their day-to-day activities. Therefore, it can be argued that currently the decision by teachers to use robots in their classrooms is often driven by availability and affordability of ready-to-use robot-based educational activities rather than by pedagogically sound considerations. Consequently, teachers' interest in adopting potentially useful robotic applications may be hindered by the difficulties they face in understanding the pedagogical value of robots as well as in integrating such innovative solutions within their settings. Furthermore, despite research having demonstrated promising applications of robots in school settings, teachers' attitudes towards robots are still mixed, as robots are not yet considered usable outside highly controlled settings or isolated structured interactions. Thus, there is a clear need to shift the focus of research from the development of educational robotic platforms to the learners, by examining the pedagogies and specific ways learners with diverse skills and capabilities undergo meaningful learning processes with robots.

3 Challenges in developing robotic and VR technologies for older adults

Robots for older people are a promising and emerging technology which opens a set of new use cases and scenarios. Concerns on robot acceptance by older people have been relieved in recent years. One of such scenarios is Ambient Assisted Living (AAL) applications. AAL focuses on providing technical assistive solutions to older adults within their homes by means of smart technologies that are seamlessly embedded within the house or objects. Although the overall goal of AAL products and services is to enable older adults to age in place, most AAL solutions focus on medical aspects such as fall detection or recognizing and monitoring habits and activities of daily living (ADLs). Robots have been used in AAL settings when an embodied user agent might be a promising device, such as when interacting with a user for cognitive stimulation goals.

Next to activation and cognitive stimulation, further use cases come up in the field of a) agent-based cognitive behavioural therapy (CBT), when anxiety, social stress, depression and – worth to highlight – loneliness are increasing issues among the older fraction of our society; or b) supporting of people with early-stage dementia during ADLs. The COVID-19 pandemic revealed more use cases for socially assistive robots.

One of the challenges of using robots with older people is how to design human-robot interfaces (HRI). Humanoid robots, or at least the application of the human metaphor within the embodiment of robots, make voice interaction an obvious choice as primary interaction modality for service robots for older adults. Furthermore, natural-language-based interaction has made tremendous advances in the past decade, being voice assistants within smartphones and smart-speakers, such as Siri on iPhone and Alexa on Amazon's Echo devices, conspicuous examples. In terms of technology acceptance, recent studies show high motivation among older adults to use voice-controlled robots within their daily lives. To address usability and overall user experience, there is a considerable amount of work on designing strategies and guidelines for voice user interfaces (VUIs) within SARs for older adults and in elderly care. Beyond voice interaction, as robots potentially feature a wide set of sensors and actuators, further interaction techniques and multi-modal interaction gain interest, including sentiment, facial expressions or gestures recognition, or providing an enriched interaction environment by means of virtual, augmented or mixed reality. Use of VR technologies to help older people is a relatively new field with studies showing that VR can be used to help with clinical conditions, provide motivation for physical rehabilitation or to improve autonomy in day-to-day activities. Challenges highlighted are the need for more representative samples, longitudinal studies and further work with older adults to better understand how VR can be adapted to suit their needs.

For interactive systems, the well-established user-centred design process underlines the strong dependency of a satisfying design on the actual use cases. This is especially true for service robots that shall be used by older users. Challenges include not only developing functional robots, but also how the robot can actually help older people to age in place, taking into account possible age-related physical or cognitive limitations. Research supports a strong focus on and need for user-centred design and co-design workflows with older adults as target user group to move towards a technological – i.e. robotic – solution for our aging society with its stressed care sector.

4 Contributions to the ICCHP-AAATE 2022 session

The contributions to this session held at the ICCHP-AAATE 2022 conference showcase the vast potential of robots and VR technologies to help children with disabilities and older adults. Combining contributions to the conference proceedings and open access compendium, the 11 articles included in this session provide a very interesting insight and possible solutions to the challenges listed in the previous sections.

On providing a robot supported education for children with ASD, Schulz et al. discuss a robot supported toolkit that aims to improve language, social and communication skills. The authors discuss ethical considerations required when working in the field and highlight the importance of involving all stakeholders to identify the challenges and contribute to a solution. Desideri argues the value of an immersive robotic telepresence system to help teachers deliver content by controlling a humanoid robot in group-based activities. Results from interviews with all the stakeholders suggest that, contrary to expectations from available literature, the predictable behaviour of a robot can be a limitation when working with children with ASD. The work presented shows how an immersive system can be flexible and allow teachers to adapt to the dynamic classes' scenarios. Finally, Chambers evaluates the effectiveness of a coding robot in classroom. Students with ASD used robots to solve coding tasks and then taught other students how to use the robots. The robots allowed for development of soft skills with both tasks, and allowed students to engage with their peers.

Zou et al. report on their work with teachers, speech therapists and psychomotor therapists to evaluate a Wizard-of-Oz interface to help children with dysgraphia. The authors present a multi-platform web interface communicating with a humanoid robot to provide different exercises and games. The final system was evaluated by 15 caregivers with positive results and suggestions for further improvements. Working with children with motor disabilities, Rojo et al. highlight the advantages of a custom exoskeleton to help with goal-directed rehabilitation tasks. The work shows the potential of having both robot-assisted and VR-based game solutions that engage children in rehabilitation tasks, and demonstrates the success of preliminary tests with end users.

To support disabled people, Bonarini provides examples of different robots that involve both players and their caregivers. The research highlights the benefits of both autonomous and remote-controlled robots, and how play can be facilitated and enjoyed by users. Van der Heide et al. describe interviews with dynamic arm support and robotic arm users to understand challenges faced by the users. Results show a need for more information and training, and the authors offer a protocol for this information provision. Thevin investigates how a VR sensitisation tool can help instructors working with blind and visually impaired people. Four professionals with different backgrounds helped co-designing the virtual environment and simulations. The article provides the perspective of instructors and answers questions around whether VR fulfils professional requirements and what the blockers might be.

The last three contributions discuss and present the acceptance of different robots for older and disabled people. Wasić et al. provide insight into the opinions and intention to use a mobile service robot from the perspective of caregivers and relatives of people with dementia. Results show more scepticism and lower acceptance among caregivers compared to relatives and authors discuss how perceived ease of use can be affected by those who are not the primary end user of the robot. An often-debated issue with robots is their appearance and how it impacts acceptance. Sehrt et al. investigate three different designs of a robot that fetches objects around a person's home. Evaluation involving both younger and older people show the difference of opinion between the two groups and re-iterated the importance of involving users in the robot design process. Finally, Prescott et al. explore design principles for social robots and present guidelines for ethical social robots with a view on "honest anthropomorphism".

While all these articles address different robotic and VR applications for different target groups, all show the critical value of user-centred co-design involving all stakeholders and illustrate methods to accomplish it. They also provide additional research evidence on the effective use of robotic and VR technologies for children with disabilities and older adults, contributing to improve the acceptance of these technologies.

Further research is still needed to assess the long-term effects of robotic and VR technologies, namely the transferability of acquired skills to other contexts. It is necessary to define standardised outcome measures such that robotic and VR interventions can be compared with other approaches. A wide consensus on the ethical use of these technologies is still to be achieved. More longitudinal studies in real-world application scenarios, involving larger samples in scientifically sound research methods, need to be conducted to prove beyond any doubt the value of robotic and VR technologies for children with disabilities and older adults. Once that is achieved, the cost of these technologies will go down, and intervention protocols and materials will be developed, allowing for its wide acceptance and use.

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