Original Manuscript

RATE

Journal of Rehabilitation and Assistive Technologies Engineering
Volume 12: 1–9

DOI: 10.1177/20556683251313773
journals.sagepub.com/home/jrt
Sage

Students perspectives on the development and deployment of an AI-enabled service robot in long-term care

Lillian Hung[1,2], Abdul-Fatawu Abdulai[1], Albin Soni[2,3], Karen Lok Yi Wong[2,4], Lily Haopu Ren[2,5], Rachel Xia[2,6] and Katharine Davies[2,7]

Abstract

The need for Artificial Intelligence (AI) in gerontology education is underscored by the potential benefits it offers in addressing loneliness and supporting social connection among older adults in long-term care (LTC) homes. While the workforce in LTC is often overburdened, AI-enabled service robots present possible solutions to enhance residents' quality of life. However, the incorporation of AI and service robots in current gerontology curricula is lacking, and the views of students on this subject remain largely unexamined. This study aims to fill this gap by capturing the perspectives of university students regarding the deployment of an AI robot, Aether, in LTC environments. In this qualitative study, we conducted focus groups with 22 university students. Our thematic analysis identified three themes: (1) Aether's anticipated usage in geriatric care: companionship support and complementing the work of staff; (2) Challenges in using Aether: technical and emotional challenges; and (3) Solutions and future possibilities: expanding functionalities and integrating personalization features. Students expressed a positive outlook on the role of AI-enabled robots while also highlighting the necessity of addressing ethical and practical considerations. To effectively integrate AI technology in gerontology education, it is essential to understand and incorporate student perspectives, attitudes, and opinions.

Keywords

Artificial intelligence (AI), robots, deployment, long-term care (LTC), university students, perspectives, people with disabilities

Date received: 22 June 2024; accepted: 10 December 2024

[1]Innovation in DEmentia and Ageing (IDEA) Lab, University of British Columbia, Vancouver, BC, Canada
[2]School of Nursing, University of British Columbia, Vancouver, BC, Canada
[3]School of Biomedical Engineering, University of British Columbia, Vancouver, BC, Canada
[4]School of Social Work, University of British Columbia, Vancouver, BC, Canada
[5]Faculty of Graduate and Postdoctoral Studies, University of British Columbia, Vancouver, BC, Canada
[6]Faculty of Science, University of British Columbia, Vancouver, BC, Canada
[7]School of Audiology & Speech Sciences, University of British Columbia, Vancouver, BC, Canada

Corresponding author:
Lillian Hung, School of Nursing, University of British Columbia, 2211 Wesbrook Mall T201, Vancouver, BC V6T 2B5, Canada.
Email: Lillian.hung@ubc.ca

Introduction

Globally, 2.3 billion people will require LTC in 2030, with demand expected to continue rising due to age longevity and the growing prevalence of chronic conditions and disabilities.[1] Confinement and restrictions on visitations have increased LTC residents' feelings of anxiety, isolation, and loneliness, creating new or exacerbating pre-existing physical and mental health concerns (e.g., depression, loneliness, cognitive decline, frailty, mobility issues).[2,3] The global effects of the COVID-19 pandemic have resulted in increased use of social robots in LTC to connect older people to the outside world safely and to help maintain their mental and physical health.[4,5] Now, it is more important than ever to develop innovative ways to overcome loneliness and improve LTC residents' safety and quality of life.

Integrating technology into support for individuals with disabilities encompasses a broad spectrum of tools, from digital assistants to advanced personal robots.[6–8] For example, palmtop personal computers equipped with audio-visual training programs have effectively enhanced independence for adults with disabilities performing community-based vocational tasks.[9] Research indicates that assistive technologies positively influence everyday activities, improving daily living, leisure, and social engagement.[10] The interactive aspect of digital technologies can provide therapeutic benefits for improving well-being and care regarding physical, cognitive, and social effects.[11] A recent review of socially assistive robots in caring for older people with dementia indicates that assistive robots show promise in fostering social interaction, supporting emotional needs, and providing companionship.[12] Companion robots can be used to address the increasing demand for healthcare for this population. The European FP7 project "CompanionAble" exemplifies this by integrating a mobile robot with a smart home system to support people with mild cognitive impairment.[13,14] The robot can remind appointments, recommend specific activities, video call with friends and relatives, facilitate cognitive stimulation through games, and store personal physical items.[14] Such functionalities were achieved through a co-design approach, gathering data from interviews and surveys to identify user needs, which informed the system's specifications.[14] Subsequent studies were followed to assess the system's value from the end-user's perspective.[15]

Similarly, the Knowledgeable Service Robots for Aging (KSERA) project produced a humanoid robot to promote older adults' independence.[16] Additionally, this project has pioneered a parametric model to define personal space for the robot's social interaction.[17] Through a series of field trials, this project found some key technological features essential for user acceptance of the robot.[16] These features include precise localization of both individuals and the robot, navigation that acknowledges the presence of humans, effective speech recognition and response, meaningful robot gestures, simulated emotions, and the capacity to maintain eye contact and share attention.

Studies also show that residents and staff have mixed perspectives and feelings towards AI-enabled and service robots. Some current studies show that older adults and healthcare staff have positive attitudes toward the integration of AI and robotics in LTC settings.[18–21] In a study by Papadopoulos et al.,[21] on care home workers' perceptions of a humanoid Socially Assistive Robots (SARs) in their LTC workplace, most healthcare workers and residents were open to using assistive robots. They saw their potential usefulness in care settings. Similarly, a survey of healthcare professionals conducted by Chen et al.[20] showed that they perceived SARs in LTC as both practical and beneficial to older adults' psychosocial well-being. Other studies reported potential risks and challenges associated with being relevant, accepted, and tailored to the needs of users.[22–28] Common concerns that have been discussed in the literature include technical issues, safety, privacy, and loss of human connection.[22,24–26,28,29]

Overall, current studies show that AI-enabled robots have the potential for supporting older people in care settings.[30–34] Incorporating AI technology and robotics into gerontological education is essential due to the increasing challenges and opportunities these innovations present in long-term care (LTC). Gerontological curricula that address ageism and inequalities can prepare students to meet the complex needs of older adults.[23] Despite the recognized advantages and varying perceptions of AI-enabled and service robots, current educational programs in gerontology have not adequately emphasized these elements, leaving a gap in the preparation of future healthcare professionals.[35–40] With the growing literature on adopting AI robotics in care settings, it is necessary to expand research to include the views of multidisciplinary students.[37,39,40]

Investigating the perspectives of young university students on using AI-enabled robots for older adults is crucial for several reasons. These students represent the next generation of healthcare professionals, technologists, and policymakers. Their attitudes and opinions will shape the future of healthcare technology and its acceptance in society. Secondly, engaging with a group generally familiar with technology can foster innovation and creativity in the design, ensuring they are adaptable and user-friendly. Additionally, understanding young students' perspectives can highlight potential ethical, social, and practical challenges in deploying AI-enabled robots in care settings, allowing for proactive solutions.[40] This exploration enriches our comprehension of the societal acceptance of such technologies and contributes to the dialogue necessary for the successful integration of AI into geriatric care.

Purpose and research question

The study aimed to understand the perspectives of university students about the use of AI-enabled robots in care settings. The research question for this project is: What are the views of university students across disciplines about the benefits, concerns, and future possibilities of using AI-enabled robots in the care of older adults?

Introducing Aether – an AI-enabled robot

Aether is a collaborative service robot with social companion functions and offers inspection services in a geriatric care setting. Aether responds to voice commands and provides entertainment features. It can map a care home while localizing itself in it and navigating around safely. Aether's skills include verbal and web-based interfaces for labelling spaces and waypoints, creating inspection routes based on waypoints and scheduling recurring inspections. Inspections include checking physical environmental hazards, such as water spills and falls. To address loneliness and promote LTC's social connections, Aether can also interact with caregivers and residents socially, such as telling jokes, broadcasting news, reading short stories, and using voice commands to welcome new people into the LTC home. Aether has proactive functions like informing users when a command is completed and when battery levels require a task to return to the charging station. Below is a photo of Aether (see Figure 1).

Figure 1. Aether, a collaborative AI-enabled service robot.

Methods

Sampling and data collection

We recruited participants with convenient sampling. In the summer of 2023, we put posters on the university campus. Students interested in the study contacted a research assistant, the third author, who scheduled them into focus groups based on availability. We conducted three focus groups with 22 students in September 2023 (see Table 1 for demographic information of participants). The participants all came from the same university in Western Canada. Each focus group had 6 to 8 people and lasted from 30 min to an hour in a research lab at the university. At the beginning of each focus group, a researcher and a research assistant collected demographic information. The research assistant then demonstrated what Aether could do and let participants interact with Aether. Following the interactions, participants were asked about their views on Aether according to a semi-structured interview guide, as shown below. The focus group discussions were digitally recorded and transcribed verbatim.

Data analysis

Our analysis followed the six-step approach by Braun and Clarke.[41,42] Step 1: All authors read and re-read the transcribed text to become familiar with the data. Step 2: Two research assistants, AS and KD, independently conducted a preliminary thematic analysis. They then compared the initial themes and presented them to the team. Step 3: An academic professor, AA guided to refine the early theme development. Step 4: AS presented the themes to the team, who discussed the data and reviewed the themes for three rounds. We resolved conflicted opinions through discussions. Step 5: Collectively, the research team further refined the themes and finalized the results to answer the research question. Step 6: LH guided the student authors to write the first draft of the manuscript, and all authors reviewed and edited the draft. Table 2 provides examples for the development of final themes.

Rigour

We adopted several measures to ensure the research rigour. For credibility, that was, the accuracy of the findings. We double-checked with participants if we understood what they said correctly during the focus groups. Our team analysis was guided by two experienced nursing professors and qualitative researchers. We included students from

Table 1. Interview guide for three focus groups.

1. How do you envision a robot such as Aether being utilized in geriatric care settings?
2. What challenges or concerns do you foresee in implementing Aether for geriatric care?
3. What are the future possibilities of using AI-enabled service robots?

Table 2. Example of thematic analysis.

Quotations	Code	Subtheme	Theme
"I think some people might find it challenging to interact with because it's not an actual person. So, it might not respond as you'd expect from a person. And that might change the direction of the conversation and the desired outcome."	Robot abilities	Emotional challenges	Challenges using Aether
"It might be cool to have a couple of voices from family members that are specific for the patient. So recognizing who the person is and bringing up the voice element, tailoring it per person."	Robot abilities	Expanding functionalities	Recommended solutions & outlook of AI

social work and engineering in the team; the diverse perspectives of the research team made our discussion and analysis robust. We also practised team reflexivity, which is embedded in our regular research meetings. We challenged and critically reflected on each other's assumptions through team discussions. Focusing on transferability ensured the findings could be applied in different contexts or settings, was enhanced by giving detailed descriptions of the research process, participants, data generation methods and context.

Ethical considerations

The study received ethics approval from the Research Ethics Board at the University of British Columbia. We booked appointments and sent consent forms and questions to participants a few days before the interview so they had time to prepare their responses to the questions. Written consents were obtained from all participants. All identifiers, including names and other details, were removed from all data to protect the confidentiality of the participants.

Findings

Demographic information of participants

The student sample participating in the study was diverse in gender, ethnicity, level and field of study, and experience with long-term care. Most were female (59.1%), while males comprised 40.9%. Their fields of study varied widely, including Nursing (22.7%) and Engineering (22.7%) as the most common, among others such as Cognitive Sciences and Occupational Therapy. Only one participant reported having a family member in long-term care; a minority of the sample (31.8%) had experience working or volunteering in such a setting. The age range of participants was 20–28,

Table 3. Demographic information of participants (N = 22).

Characteristics	*N*	%
Gender		
Female	13	59.1
Male	9	40.9
Ethnicity		
White	2	9.1
South Asian	8	36.4
Southeast Asian	2	9.1
East Asian	5	22.7
Middle Eastern/North African/Southwest Asian	3	13.6
Prefer not to say	2	9.1
Level of study		
Undergraduate	18	81.8
Graduate	4	18.2
Field of study		
Cognitive sciences/systems	4	18.2
Nursing	5	22.7
Occupational therapy	1	4.5
Pharmacological science	1	4.5
Engineering	5	22.7
Science	2	9.1
Sociology	1	4.5
Kinesiology	2	9.1
Prefer not to say	1	4.5
Any family member in long-term care?	1	4.5
Yes	1	4.5
No	21	95.5
Any experience working or volunteering in long-term care?		
Yes	7	31.8
No	15	68.2
Age	Range: 20–28	
	Mean: 21.5	

with an average age of 21.5 years. See Table 3-Demographic information of participants as below.

Themes

Analysis of the data revealed three overarching themes related to the use of AI in care for older adults: (1) how Aether can be utilized, (2) the possible challenges of using Aether, and (3) the recommended solutions and outlook of AI-enabled robots. See Figure 2.

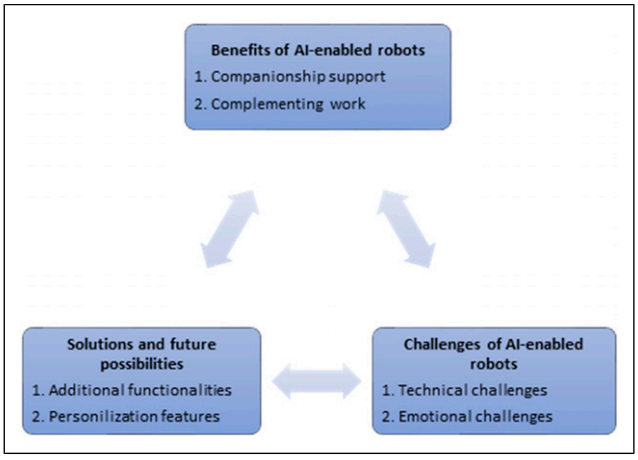

Figure 2. Themes.

Theme 1: Aether's anticipated usage. When participants were asked about how Aether can be utilized in geriatric care, they highlighted companionship support and complementing the work of healthcare professionals as the primary means to enhance the quality of care.

Sub-theme 1.1: Companionship support. Participants acknowledged the potential lonely environment of geriatric care and understood how the limited number of healthcare professionals contributes to this issue. Results show that participants specifically indicated that the robot could act as a companion to the residents, keeping them engaged and mentally active through conversation, jokes, games, and other methods. After understanding the capabilities of the robot, one participant stated: *"It could be used if the older person needs something or has a specific request, or maybe if they just want to talk."*

Furthermore, Aether's ability to hold conversations on countless topics was noted by participants to enhance its role as a companion. Residents could discuss topics such as childhood dishes and favorite songs that staff may not know. One participant commented on how Aether's potential for companionship support was similar to how she used ChatGPT to engage her mother, who is living with dementia.

> "*My mom loves animals, and every night, I would ask ChatGPT to write me a story about chickens. And let's say tonight was about chickens, and tomorrow was about horses. I would ask her about chickens and horses on the second night, so she goes backwards. And I feel like after a week or two, she started remembering more and more about questions in the past, and I would refer to some stories later, and she would remember them. Maybe this robot can engage older adults in similar acts.*"

According to participants, using the robot to foster companionship will allow health professionals to dedicate their time to more crucial tasks.

Sub-theme 1.2: Complementing the work of staff. In addition to providing companionship, participants indicated that Aether could help complement and, in some cases, replace the work of healthcare professionals. Areas such as assisting staff to check on the safety and welfare of residents, marking safety hazards around the care home settings (e.g., water spillage), and possibly serving medications to residents. One participant stated, *"It can remind me what time and what medications [are] required. Things that are very scheduled for a patient.*

Theme 2: Challenges in using Aether. When asked about the potential challenges of the use of Aether in geriatric care homes, participants pointed out several foreseeable challenges that were categorized under technical challenges and emotional challenges related to the use of the robot.

Sub-theme 2.1: Technical challenges. Participants indicated technical challenges that could impede the use of the robot. They specifically mentioned problems like a possible limited battery lifespan, Wi-Fi connectivity issues, the inability of the robot to recognize strange objects misplaced in hallways, having a muffled voice, and the possibility of being pushed down or stumbled over by an "agitated resident." One participant indicated how the muffled voice can affect people with dementia and their ability to communicate with the robot by stating, "*in my experience interacting with people with dementia, sometimes it takes a long time to structure a sentence. I don't know if [Aether] will parse the whole sentence before responding or just cut you off – which is pretty bad*". The participants also talked about the inability of the robot to recognize or detect voices from different residents or emojis.

Sub-theme 2.2: Emotional challenges. The participants indicated that Aether might be unable to recognize and respond to people's emotional needs. This concern was particularly expressed for older persons with dementia who may not be able to properly communicate their emotional needs. While participants indicated that the robot could possibly replace some human tasks in the care homes, they

acknowledge that the robot may not be able to empathize with residents or connect with them beyond what residents express verbally. One participant stated, "*Maybe one thing that might be a bit challenging, let's say you're telling something emotional about it or you are having some feelings that cannot communicate because of your dementia. It might not have a stronger sense of sympathy than a person might. So that could be something that makes it harder for somebody to feel comforted or at ease with*."

Theme 3: Solutions and future possibilities. Participants also recommended possible solutions to the challenges above and expressed their thoughts on the future possibilities of AI-enabled robots in this context.

Sub-theme 3.1: Expanding functionalities. To address the technical challenges, participants specifically suggested incorporating additional functionalities and integrating personalization features, including item delivery, peripheral vision, redesigning Aether to respond to gestures, and including emotion detectors to respond to residents' emotional reactions without any verbal input. Other participants suggested providing tutorial videos for residents and staff on better understanding and using the robot. Others suggested having icons on the robot's screen so that residents, particularly those with dementia, can interact with the robot without verbal input. One participant stated,

> "*People who are far away might need the services of the robot. Do they have to shout? For example, if someone waves at the robot or something, rather than call it from afar, the robot might know when to stop attending to a person and go to another person that might need their services*."

Sub-theme 3.2: Integrating personalization features. The participants suggested that Aether should contain personalization features that would enable it to respond to residents in a unique way. They indicated that each resident is unique, and Aether should be able to react accordingly. Participants also suggested that the robot should be able to have "something like emotion detectors" where they can read people's emotional reactions without any verbal input. Regarding emotional support, participants recommended that residents, especially those who faced difficult life situations and require emotional support, should be able to use the robot to connect with loved ones. One participant stated:

> "*Instead of a smiley face emoji, it could return to personalization. Say an older adult misses their loved ones; Aether could show a picture of them and make it sound like the kid is speaking in real-time. The older adults could feel that, although my loved ones are not here, I still have that kind of bond." Participants also talked about including emotion detectors so that the robot could detect how people feel without verbally telling it*."

Participants also acknowledged the growing diversity in the Canadian population and suggested that the robot responds to such diversity, particularly for residents who cannot speak English or French.

Discussion and implications

This study investigated the perspective of a diverse group of young university students to better understand their perceptions about using AI-enabled robots to care for older adults. The age range of our student participants was relatively young, 20–28, with an average age of 21.5 years. Older people with disabilities often need support to use technology. We know older people with positive attitudes toward robots were more likely to use robots, and those who used robots showed improved attitudes toward robots over time.[43,44] It is reasonable to think young people with positive attitudes toward AI robots will be more likely to support the development and use of robots for older adults. In this study, the student participants expressed a multifaceted view of using AI-enabled robots in geriatric care. After interacting with Aether in the focus groups, they told us the relevance and usefulness of the robot in supporting geriatric care. Students envisioned Aether fulfilling a dual role in long-term care homes: providing companionship support and complementing healthcare professionals' work. Students expressed optimism that the application of AI can provide substantial support for the care of older people. They perceived AI advancements as an opportunity to enhance personalized care and offer companionship to older adults, especially those with dementia. The potential for Aether to offer cognitive engagement through storytelling or conversation is noteworthy, as reflected in one participant's use of story-based interaction with a family member. The results of this study are similar to a previous study by Young et al.,[40] in which university students identified diverse perspectives regarding the risks and benefits of implementing telepresence robots in long-term care. Student participants in the telepresence robot study emphasized the importance of their own voices and views of older adults for creating more equitable decision-making and advocating for innovation in care for older persons.

Current literature tends to advocate AI tools as promising solutions that will facilitate and enhance human work and not replace the work of healthcare providers.[45] Students' perspectives on robots' function in medication reminders, cognitive stimulations and improving quality of life align with what has been reported in recent studies.[46] The students in our study were sensitive to the ethical implications, such as the extent to which emotional needs can or should be met by non-human entities. Care delivery by freeing up

human caregivers to concentrate on tasks requiring a personal touch. They stressed the importance of ensuring that using robots does not reduce meaningful human interaction but supplements it, providing a balance between technological efficiency and compassionate care. Similar concerns were noted in the literature, reported by healthcare providers.[47]

In the focus groups, the students were very interested in the social functions of Aether as they had opportunities to have conversations and physically interact with the robot. Many found that integrating AI-enabled robots with conversational capabilities in long-term care settings presents an important opportunity to enhance the care of residents while supporting staff members in their duties. Most of the student participants came from a science discipline. Also, being digital natives, they tend to bring a positive perspective to the potential functions of robots in the care of older adults. They imagined robots not just as tools for health monitoring and physical support but as integral components of a care system. The robots were perceived as facilitating virtual social interactions, providing entertainment, and assisting with exercise and rehabilitation. AI robots like Aether were viewed as helpful companions, offering engagement to residents, particularly those with dementia, through personalized conversations, reminiscence, and cognitive stimulation.

The students also brought up concerns related to technical issues like limited battery life, network connectivity, and object recognition, alongside the robot's interaction limitations with people with dementia, which could hinder effective operation. Students raised concerns about the robot's inability to fully empathize or to understand non-verbal cues from residents with dementia, which presents a significant limitation. While Aether might handle specific tasks, the subtleties of human emotion and connection involve high complexity. Students in the focus groups did not voice concerns about the potential risks of triggering previous trauma that the conversation may bring in human-robot interactions. The student spoke more about privacy concerns, the potential for decreased human interaction, and the need for staff training on effectively integrating these robots into care practices. Students stressed that ensuring the technology is used to supplement, rather than replace, human care is essential to maintaining quality care. More studies are needed to explore the benefits and risks of personalizing the robot's interactions and avoiding bias within AI programming to ensure fairness, equity, and accessibility in robotic assistance for geriatric care. Experts in AI ethics should be involved in future studies that delve into the ethical implications of deploying AI robots among vulnerable groups, such as older adults with cognitive impairments. To ensure AI's safe and responsible application in geriatric care, we must bolster regulatory frameworks, policies, and strategies that minimize risks and enhance protections.

For future possibilities, students proposed expanding Aether's functionalities to recognize gestures and peripheral vision to avoid collisions. They recommended personalization features enabling Aether to tailor interactions to individual needs, potentially extending to non-verbal emotional detectors and ways to foster connections with residents' loved ones. Considering Canada's cultural diversity, language inclusivity was also suggested, enabling residents who are non-native English speakers to communicate more comfortably. In the study of Sawik et al.,[48] older participants and their caregivers both underscore that the introduction of the robot must be thoroughly planned, include comprehensive training, and take ethical and practical issues into account.

Limitations

Our study has the following limitations. Firstly, all our participants are from the same university in Canada. Future research should include young people at various levels of education and in different countries. Also, our participants had a narrowed age range, 20–28. Future research may recruit participants from a broader range of ages to examine whether our findings can be applied across various age groups. Another limitation of the study is that the students only had limited time to interact with the robot. They could not fully experience the challenges and benefits the robot may bring. It will also be interesting to compare the perspectives of students from science and art backgrounds and those of older adults and young students. Intergenerational research with AI robots could help clarify whether intergenerational interacting experiences could change attitudes toward AI robots. Longitudinal studies are needed to focus on evaluating the impacts of these technologies on resident well-being, staff satisfaction, and the overall care environment.

Conclusion

Students' insights present both potentials and concerns about introducing AI in care to older adults, emphasizing the importance of ethical considerations in technology implementation. While AI-enabled robots with conversational capabilities offer considerable potential to improve the quality of life for residents in long-term care and assist staff in their caregiving roles, their deployment must be approached with a strategic understanding of both the opportunities and challenges. Future research should focus on evaluating the impacts of these technologies on resident well-being, staff satisfaction, and the overall care environment. Multiple insights informed by young interdisciplinary students, healthcare professionals, and ethics experts will help develop guidelines that ensure the responsible and beneficial use of AI for the care of older adults

in care settings. The escalating shortage of healthcare professionals in geriatric care underscores the need for innovative solutions like AI-enabled robots to assist in caring for older adults. These advanced technologies may help mitigate workforce constraints by providing support services such as companionship and routine assistance. More research is needed to understand the emerging relationship between AI and humans (staff and older adults) in our future geriatric care.

Acknowledgements

We would like to thank participants in the study and funding support by the Canada Research Chair in Senior Care (GR021223).

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This study supported by funding from The Canada Research Chair in Senior Care (grant number: GR021222).

ORCID iDs

Karen Lok Yi Wong https://orcid.org/0000-0002-4079-9123
Lily Haopu Ren https://orcid.org/0009-0008-0969-0980
Rachel Xia https://orcid.org/0009-0004-1681-9261

References

1. Addati L, Cattaneo U, Esquivel V, et al. *Care work and care jobs for the future of decent work*. Geneva, Switzerland: International Labour Organization, 2018.
2. Office of the Provincial Health Officer and BC Centre for Disease Control. Examining the societal consequences of the COVID-19 pandemic: social isolation of residents in long-term care & assisted living. https://www.bccdc.ca/Health-Professionals-Site/Documents/societal_consequences/Social_Isolation_LTC.pdf (2021).
3. Santini ZI, Jose PE, York Cornwell E, et al. Social disconnectedness, perceived isolation, and symptoms of depression and anxiety among older Americans (NSHAP): a longitudinal mediation analysis. *Lancet Public Health* 2020; 5: e62–e70.
4. Getson C and Nejat G. The adoption of socially assistive robots for long-term care: during COVID-19 and in a post-pandemic society. *Health Manag Forum* 2022; 35: 301–309.
5. Van Assche M, Moreels T, Petrovic M, et al. The role of a socially assistive robot in enabling older adults with mild cognitive impairment to cope with the measures of the COVID-19 lockdown: a qualitative study. *Scand J Occup Ther* 2023; 30: 42–52.
6. Braddock D, Rizzolo MC, Thompson M, et al. Emerging technologies and cognitive disability. *J Spec Educ Technol* 2004; 19: 49–56.
7. Pradhan A, Mehta K and Findlater L. 'Accessibility came by accident': use of voice-controlled intelligent personal assistants by people with disabilities. In: Proceedings of the 2018 CHI conference on human factors in computing systems, Montreal, QC, 21–26 April 2018, pp. 1–13. Association for Computing Machinery.
8. Tanabe S, Saitoh E, Koyama S, et al. Designing a robotic smart home for everyone, especially the elderly and people with disabilities. *Fujita Med J* 2019; 5: 31–35.
9. Davies DK, Stock SE and Wehmeyer ML. Enhancing independent task performance for individuals with mental retardation through use of a handheld self-directed visual and audio prompting system. *Educ Train Ment Retard Dev Disabil* 2002; 37: 209–218.
10. Hammel J, Lai J-S and Heller T. The impact of assistive technology and environmental interventions on function and living situation status with people who are ageing with developmental disabilities. *Disabil Rehabil* 2002; 24: 93–105.
11. Niemelä M and Melkas H. Robots as social and physical assistants in elderly care. In: Toivonen M and Saari E (eds) *Human-centered digitalization and services*. Singapore: Springer Nature, 2019, pp. 177–197.
12. Yu C, Sommerlad A, Sakure L, et al. Socially assistive robots for people with dementia: systematic review and meta-analysis of feasibility, acceptability and the effect on cognition, neuropsychiatric symptoms and quality of life. *Ageing Res Rev* 2022; 78: 101633.
13. Badii A, Etxeberria I, Huijnen C, et al. Companionable: graceful integration of mobile robot companion with a smart home environment. *Gerontechnology* 2009; 8: 181.
14. Gross H-M, Schroeter C, Mueller S, et al. Further progress towards a home robot companion for people with mild cognitive impairment. In: 2012 IEEE international conference on systems, man, and cybernetics (SMC), Seoul, Korea (South), 14–17 October 2012, pp. 637–644. IEEE.
15. Schroeter C, Mueller S, Volkhardt M, et al. Realization and user evaluation of a companion robot for people with mild cognitive impairments. In: 2013 IEEE international conference on robotics and automation, Karlsruhe, Germany, 6–10 May 2013, pp. 1153–1159. IEEE.
16. Johnson DO, Cuijpers RH, Juola JF, et al. Socially assistive robots: a comprehensive approach to extending independent living. *Int J Soc Robot* 2014; 6: 195–211.
17. Torta E, Cuijpers RH and Juola JF. Design of a parametric model of personal space for robotic social navigation. *Int J Soc Robot* 2013; 5: 357–365.
18. Beer JM, Prakash A, Smarr C-A, et al. Older users' acceptance of an assistive robot: attitudinal changes following brief exposure. *Gerontechnology* 2017; 16: 21–36.
19. Bedaf S, Marti P and De Witte L. What are the preferred characteristics of a service robot for the elderly? A multi-

country focus group study with older adults and caregivers. *Assist Technol* 2019; 31: 147–157.
20. Chen S-C, Jones C and Moyle W. Health professional and workers attitudes towards the use of social robots for older adults in long-term care. *Int J Soc Robot* 2020; 12: 1135–1147.
21. Papadopoulos I, Ali S, Papadopoulos C, et al. A qualitative exploration of care homes workers' views and training needs in relation to the use of socially assistive humanoid robots in their workplace. *Int J Older People Nurs* 2022; 17: e12432.
22. Christoforou EG, Avgousti S, Ramdani N, et al. The upcoming role for nursing and assistive robotics: opportunities and challenges ahead. *Front Digit Health* 2020; 2: 585656. DOI: 10.3389/fdgth.2020.585656.
23. Chu CH, Nyrup R, Leslie K, et al. Digital ageism: challenges and opportunities in artificial intelligence for older adults. *Gerontol* 2022; 62: 947–955.
24. Coco K, Kangasniemi M and Rantanen T. Care personnel's attitudes and fears toward care robots in elderly care: a comparison of data from the care personnel in Finland and Japan. *J Nurs Scholarsh* 2018; 50: 634–644.
25. Cortellessa G, Benedictis RD, Fracasso F, et al. AI and robotics to help older adults: revisiting projects in search of lessons learned. *Paladyn J Behav Rob* 2021; 12: 356–378.
26. Hung L, Mann J, Perry J, et al. Technological risks and ethical implications of using robots in long-term care. *J Rehabil Assist Technol Eng* 2022; 9: 20556683221106917.
27. Rantanen T, Lehto P, Vuorinen P, et al. The adoption of care robots in home care-a survey on the attitudes of Finnish home care personnel. *J Clin Nurs* 2018; 27: 1846–1859.
28. Vandemeulebroucke T, Dzi K and Gastmans C. Older adults' experiences with and perceptions of the use of socially assistive robots in aged care: a systematic review of quantitative evidence. *Arch Gerontol Geriatr* 2021; 95: 104399.
29. Bedaf S, Marti P, Amirabdollahian F, et al. A multi-perspective evaluation of a service robot for seniors: the voice of different stakeholders. *Disabil Rehabil Assist Technol* 2018; 13: 592–599.
30. Asgharian P, Panchea AM and Ferland F. A review on the use of mobile service robots in elderly care. *Robotics* 2022; 11: 127.
31. Ma B, Yang J, Wong FKY, et al. Artificial intelligence in elderly healthcare: a scoping review. *Ageing Res Rev* 2023; 83: 101808.
32. Neves BB, Petersen A, Vered M, et al. Artificial intelligence in long-term care: technological promise, aging anxieties, and sociotechnical ageism. *J Appl Gerontol* 2023; 42: 1274–1282.
33. Padhan S, Mohapatra A, Ramasamy SK, et al. Artificial intelligence (AI) and robotics in elderly healthcare: enabling independence and quality of life. *Cureus* 2023; 15(8): e42905. DOI: 10.7759/cureus.42905.
34. Ribeiro T, Gonçalves F, Garcia IS, et al. CHARMIE: a collaborative healthcare and home service and assistant robot for elderly care. *Appl Sci* 2021; 11: 7248.
35. Chao P-J, Cheng Y-H, Liu Y-H, et al. University students' attitudes toward adoption of mobile health application for serving older people. *Sensor Mater* 2023; 35: 2581–2601.
36. Ekwonye AU, Malek A, Farah I, et al. "Aging is beautiful and graceful:" exploring college students' perceptions of aging, older adults, and future older selves. *Educ Gerontol* 2023; 49: 803–816.
37. Łukasik S, Tobis S, Kropińska S, et al. Role of assistive robots in the care of older people: survey study among medical and nursing students. *J Med Internet Res* 2020; 22: e18003.
38. Teng M, Singla R, Yau O, et al. Health care students' perspectives on artificial intelligence: countrywide survey in Canada. *JMIR Med Educ* 2022; 8: e33390.
39. Tobis S, Cylkowska-Nowak M, Wieczorowska-Tobis K, et al. Occupational therapy students' perceptions of the role of robots in the care for older people living in the community. *Occup Ther Int* 2017; 2017: e9592405.
40. Young E, Hung L, Wong J, et al. The perceptions of university students on technological and ethical risks of using robots in long-term care homes. *Front Robot AI* 2023; 10: 1268386. DOI: 10.3389/frobt.2023.1268386.
41. Braun V and Clarke V. Using thematic analysis in psychology. *Qual Res Psychol* 2006; 3: 77–101.
42. Braun V and Clarke V. Reflecting on reflexive thematic analysis. *Qual Res Sport Exerc Health* 2019; 11: 589–597.
43. Hung L, Gregorio M, Mann J, et al. Exploring the perceptions of people with dementia about the social robot PARO in a hospital setting. *Dement Lond Engl* 2021; 20: 485–504.
44. Stafford RQ, MacDonald BA, Li X, et al. Older people's prior robot attitudes influence evaluations of a conversational robot. *Int J Soc Robot* 2014; 6: 281–297.
45. Bohr A and Memarzadeh K. Chapter 2: The rise of artificial intelligence in healthcare applications. In: Bohr A and Memarzadeh K (eds), *Artificial Intelligence in Healthcare*. (pp. 25–60). Academic Press. 2020.
46. Obayashi K, Kodate N and Masuyama S. Measuring the impact of age, gender and dementia on communication-robot interventions in residential care homes. *Geriatr Gerontol Int* 2020; 20: 373–378.
47. Trainum K, Tunis R, Xie B, et al. Robots in assisted living facilities: scoping review. *JMIR Aging* 2023; 6: e42652.
48. Sawik B, Tobis S, Baum E, et al. Robots for elderly care: review, multi-criteria optimization model and qualitative case study. *Healthcare* 2023; 11: 1286.