Assessment of personal care and medical robots from older adults’ perspective

K. M. Goher1*, N. Mansouri2 and S. O. Fadlallah3

Abstract
Demographic reports indicate that population of older adults is growing significantly over the world and in particular in developed nations. Consequently, there are a noticeable number of demands for certain services such as health-care systems and assistive medical robots and devices. In today’s world, different types of robots play substantial roles specifically in medical sector to facilitate human life, especially older adults. Assistive medical robots and devices are created in various designs to fulfill specific needs of older adults. Though medical robots are utilized widely by senior citizens, it is dramatic to find out into what extent assistive robots satisfy their needs and expectations. This paper reviews various assessments of assistive medical robots from older adults’ perspectives with the purpose of identifying senior citizen’s needs, expectations, and preferences. On the other hand, these kinds of assessments inform robot designers, developers, and programmers to come up with robots fulfilling elderly’s needs while improving their life quality.

Keywords: Assistive medical robots and devices, Robot assessment, Older adults’ perspective, Assistive walking devices, Information and communication technology, Older adults’ needs assessment

Introduction
Recent decades have witnessed a noticeable development in information and communication technology (ICT). This development has led to advent of various types of robots in vast majority of industries, namely manufacturing, military, medical and health care, entertainment, and household [73]. In the medical sector, assistive medical robots and devices play substantial role in senior citizens lives. The population of senior citizens is growing substantially over the world [5, 48]; therefore, the demand for specific needs rises [13, 52, 53]. Growth in aging population results in noticeable number of issues such as dearth of health-care centers, professionals, and services [30] as well as huge burdens of health-care costs [1]. In order to diminish costs related to readmission and transportation, and also to ameliorate quality of health-care services and older adult’s independency, health-care services are shifted to older adults’ home from medical centers [9]. Therefore, different types of assistive medical robots, namely remote presence robot, paro-robot, telerobot, skillegent robot, RIBA [1], and devices such as wheeled walkers [7, 57], are created to fulfill various needs and compensate disabilities. Assistive medical robots and devices not only have facilitated older adult’s tasks, but also have promoted their life quality and kept their autonomy [56]. For instance, mobile manipulated robot offers to bring object(s) to older adults or by their request [2], telerobot monitors health condition and medication of elderly [1], pet robot companies older adults [6], and rolling walker assists elderly to have better mobility, stability, and balance [68].

Overview and contribution
There are a noticeable number of assistive robots and devices to empower older adults to carry out their daily routine tasks independently. Yet in accordance with conducted research studies, older adults do not incline...
toward the use of technology. In other words, there is a gap for improving assistive technology to increase robot acceptance and fulfill elderly’s needs. The authors of this paper provide a review of assessment of assistive medical robots and devices from older adults’ perspective to identify the factors associated with assistive technology acceptance. The authors of this paper believe that adequate and accurate understanding of senior citizens’ needs and expectations will inform robot designers, programmers, and developers to create user-friendly and user-centered robots and devices meeting required features and functions. We aim at identifying the reasons causing decline of robot acceptance and also to assess older adults’ needs and expectations. We believe that in order to boost acceptance of older adults to use robots, it is important to assess not only their needs and expectations, but also their attitudes toward technology.

Paper organization
This paper is organized as follows: “Assistive technologies overview” section presents a detailed overview of assistive technologies and their associated features. “Assessment of assistive medical robots” section introduces an overview of assessment of medical robots from older adults’ perspectives. In “Assessment of walking devices and related technologies” section, we investigate the assessment of assistive walking aids and in particular walking devices.

“Older adults satisfaction of other assistive devices” section focuses on presenting older adults’ satisfaction of other assistive devices. The paper is concluded in “Conclusion” section where we emphasize on specific attitudes of older adults toward the use of assistive technologies in daily life.

Assistive technologies overview
Different types of robots have been developed to provide various aids for older adults. The information in Table 1 reveals that enhancements in technology have compensated elderly’s disabilities, which improved their life quality and health conditions through remote controlling robots [19]. Moreover, assistive robots and devices are developed to provide physical aid to elderly to accomplish their routine activities such as feeding, management of medication, and emergency control [35, 55]. Besides, it is obvious that older adults benefit from assistive robots and devices to retain their autonomy, diminish health-care needs, accomplish daily tasks, and increase social communication [10]. Albeit a great number of useful assistive robots and devices are developed, yet some older adults decline to accept technology in their routine life [13].

Assessment of assistive medical robots
Though a great number of assistive medical robots and devices are developed for older adults, yet there is lack of research studies related to acceptance of assistive technology from older adults and their caretakers’ perspective [35]. We believe that it is important to conduct further research work surrounding this field. The declined acceptance of older adults of assistive technologies is mainly related to the limited knowledge and the embarrassed emotions [27]. Moreover, [17] it is found out that there are two primary factors affecting use of assistive technology: abilities and attitudes. In accordance with conducted ethnographic studies, older adults incline to utilize assistive technology when the dignity and autonomy of them are maintained [26]. Ethnographic studies provided a series of recommendations to robot designers and developers. The recommendations are in terms of robot dimensions which should be fit within elderly’s place, robot interface which should be easy to use, and interaction feature which should meet elderly’s abilities.

Older adults’ attitude toward health-care robots
There are two primary factors influence adoption of technology by older adults: ease of use and usefulness [22, 33, 62]. Ease of use factor refers to level of older people’s knowledge about assistive technology. Older adults, who are intermediate and familiar with assistive technology, show positive perspectives [13, 25]. Robot usefulness refers to provision of physical assistance and task monitoring such as carrying and picking up a heavy item [13]. The behavior of older adults has proved that elderly decline to utilize assistive robots if their tasks are not found useful [41]. Findings of the aforementioned research studies have shown that robot functionalities, related to nonsocial tasks and robot interaction, are the most influential factors in technology acceptance by the older people [60].

It is stated that older adults commonly refuse to use assistive technology because of being novice at accomplishing tasks with technology [20]. In addition, it is said that older adults, unlike young people, are concerned about learning technology skills. This tends to make them refusing to use technology [23]. From a large-scale research study, it is found that older adults show positive attitudes toward assistive technology adoption when they are assisted with significant task [25]. A number of research studies revealed that cost is one of the primary factors which make older people concerned. They incline to adopt assistive technology if the advantages outweigh the cost [15, 45, 59]. In accordance with previous studies, the use of technology appeals older adults if it only offers them greater autonomy [51, 65]. Moreover, unlike
youngsters, older adults show different attitude toward technology acceptance. Older adults decline to trust on technology, and also they think it is complex to utilize. Moreover, the behaviors of older adults have proved that when they face difficulties, they tend to give up rather than asking for help [28].

In other conducted research work by Wu et al. [72], they investigated adoption of assistive robots by elderly and also analyzed elderly’s perspective after 1 month of direct interaction with assistive robots. Two groups of cognitively intact healthy (CIH) and mild cognitive impairment (MCI) participated in this study. Both groups declined to show willingness to utilize assistive robots. Moreover, negative attitudes toward robots and negative image of robots were noticed. The same attitude has been reported after carrying the same study for one more month of interaction. Older people responded that assistive robots are not useful, whereas they found robots safe, interesting, and easy to use. This finding reveals a total contrast with previous studies, indicating that older adults’ behavior toward assistive robots ameliorates after direct interaction [39, 63]. It has been noticed in this study that older people found themselves not in needs of assistive robots.

In the work done by Morris et al. [49] and Heart and Kalderon [32], elderly showed fear of dehumanization.

Table 1 Assitive medical robots and devices for older adults

| Category                        | Description and primary functions                                                                                                                                                                                                 | Research contributions                                                                                                                                                                                                                                                                 |
|---------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Telerobots                      | The functions of this type of robot are to facilitate communication with medical professionals, to monitor injuries, and also to follow up with family members [1]                                                                 | Pearl and Wakamuru robot [46], robobot [46], skilligent robot [1], and RIBA [61]                                                                                                                                                                                                      |
| Mobile manipulator robots       | Mobile manipulator robots focus on disabled and older adults with the intention of furnishing requested item to either older adult or disabled to satisfy their needs [2]                                                       | Mobile manipulator robot [2]                                                                                                                                                                                                                                                               |
| Assistive walking devices       | Assistive walking devices are primarily created to compensate older adults’ disabilities, while maintaining better balance, stability, and walking support. They also help in facilitating mobility, maneuvering, walking, standing, sitting, and independency. These devices are enhanced with information and communication technology to detect fall incidents, fall prevention, and also ameliorate alarming system. The enhancement in walking devices reduces waiting time to receive assistance [31]. Furthermore, ICT assists medical professionals and caretakers to monitor fall incidents closely [14] | Rolling walker [68], knee walker [3], crutch [40], and cane [69]                                                                                                                                                                                                                       |
| Animal-like robots              | Albeit a great number of medical professionals believe that animals have deleterious health consequences such as injuries and infection, a noticeable number of them subscribe to the belief that interaction with animal leads to emotive effects to patients. For this reason, animal robots with the purpose of communicating with and entertaining older adults, ameliorating health condition, and relieving distressing imitate animal behaviors [70] | Paro-robot [71], NeCoRo [11], AIBO [11], bandit [11], and accompany robots [36]                                                                                                                                                                                                       |
| Home health-care robots (HHRs)  | When the primary tasks of a robot are associated with home health care, the robot is called home health-care robot. These kinds of robots assist medical specialists to monitor elderly at their houses. HHRs are designed with the purpose of ameliorating autonomy of older adults as well as improving their well-being to alleviate long-term hospitalization in medical centers. Home health-care services consist of substantial services such as professional and physical nursing care, speech treatment, and medical social services [1] | Tele-operated robot [50]                                                                                                                                                                                                                                                                |
| Humanoid robots                 | This type of robot primarily identifies older adults’ needs and also provides services for both elderslies and their caregivers. The main features of this robot are to provide medication reminder, to detect issues and take action to inform caregiver, manage plans, and assist elderly to take off [44] | iCub robot and nao robot [21]                                                                                                                                                                                                                                                             |
toward adoption of assistive robots. Ethical and societal issues were considered as a barrier of adoption of assistive technologies. Participants responded that use of assistive robots gives them the impression of being watched and monitored. This gives rise to exceeding the importance of elderly’s privacy.

Beer and Takayama [10] assessed mobile remote presence (MRP) systems from older adults’ point of view. They reported that benefits of MRP systems were obvious to elderly; therefore, older adults showed willing to utilize such a system in social and medical contexts. Older adults had positive attitudes to number of benefits from assistive robots, namely decreased traveling cost, improved visualization, and reduction in social isolation. On the other hand, they were concerned about call management, lack of face-to-face communication, and privacy.

Older adults’ preferences from health-care robot’s functions
Older people prefer to have far more communication with health-care robots. For instance, they prefer to converse with robots about the topic related to robot itself, rather than talking about health-care and activities [41]. Moreover, older people consider robots as a performance-directed machine, rather than a social device [25]. Broadbent et al. [13] conducted an important research work to investigate not only older adults’ perspectives toward health-care robots, but also their caretakers as well. In their study, it was found that caregivers were concerned about their jobs that may be replaced by health-care robots. On the other side, this research highlighted that older adults have positive perspective about health-care robot apart from concerns related to reliability, privacy, and safety. In terms of robot’s functionality, fall detection feature appealed vast majority of elderly. Moreover, functions such as big buttons, clear voice, and visible screens are significantly favorable. Older adults prefer robots to automatically detect and monitor fall incidents without wearing any device or being nearby a call button.

Past research work revealed that in terms of robot appearance, unlike youngsters, older adults prefer less human-like and more serious robots [4, 16, 58]. It is stated that the robot’s tasks should be commensurate with appearance and shape. Moreover, the robot is not necessarily required to be human-like if its functions do not require. In terms of size, adjustable robots with minimum of five feet are highly accepted.

Further research work has been conducted by Smarr et al. [60] with the purpose of identifying the tasks that need robot assistance. In this study, tasks were categorized into three categories: self-maintenance activities of daily living (ADLs), instrumental activities for daily living (IADLs), and enhanced activities of daily living (EADLs). Assistance for IADL tasks consists of housekeeping such as laundry and medication reminder. On the other hand, tasks such as new learning and pastime refer to EADL. Older people prefer to have robot assistance rather than human assistance for IADLs and then EADLs. In contrast, it was found that older people favor to have assistance for ADLs and also some specific tasks of IADLs and EADLs, namely decision on medication, meal preparation, and social interaction. The results of this study are similar to Broadbent et al. [13] findings. This makes us able to conclude that older adults prefer to have robot assistance for monitoring and physical aid, while they prefer human aid for decision-making tasks.

Considering medication management as a prime example, older adults prefer health-care robots to either bring them medicine or remind them of the regular doses. However, they favor human assistance to make decision what and/or when medicine to take. This concept assists designers and developers of health-care robots to furnish robot with high level of intelligent to enable them to make the right decision.

Assessment of walking devices and related technologies
Wheeled walkers provide walking support for a big number of older people to compensate their moving and walking disabilities. Wheeled walkers are used primarily for maintaining mobility and balance [8, 57] as well as alleviating fall incidents [29]. Though they are used by a noticeable number of users, yet there is a need for improvement to fulfill older adults’ needs and expectations [42]. This section gives a review of previous conducted research studies on the assessment of assistive walking devices from older adults’ perspective.

Wheeled walkers limitations
Van Riel et al. [67] reported that the use of wheeled walkers usually results in severe fall injuries. Based on previous research by Lindemann et al. [42], there are various limitations associated with the use of wheeled walkers which causes serious fall incidents to older adults including walking backward, downhill and uphill, holding an item when fronting obstacle(s), encountering obstacles such as stairs in public transportation, and walking on uneven surfaces. Older adults encounter difficulties to retain their balance and control to open a door which is in reverse direction of their assistive wheeled walker. This situation becomes more challenging when a user holds an item while passing through a door. For this reason, older adults stated that it is easier to walk through a door or to open the door without wheeled walker. Despite there have been numerous approaches and developments
to overcome the mentioned limitations of wheeled walkers, the proposed solutions were not satisfactory. For instance, walking backward through a door using a walker is still a challenge for most users. This is due to the fact that front wheels of the walker provide 360° rotation, whereas the rotation of back wheels is restricted. Rentzschler et al. [54] recommended a walker with a rotation feature and intelligent obstacle prevention to overcome those limitations.

**Older adults’ satisfaction of other assistive devices**

A noticeable number of research works have been accomplished to evaluate older adults’ experience feedback and satisfaction level from assistive technologies. Privacy is considered to have a significant concern to older people. For instance, they prefer to have faint pictures at their private places of the house (bedrooms) while they do not hesitate to have transparent images in other general areas (dining room and lounge) [43, 47]. Cameras and visual surveillance systems are unfavorable to the older adults [64]. Moreover, disabilities in having control over the assistive device are one of the main reasons that older people decline to adopt ICT [18, 38, 43, 66]. They also prefer having complete control over the assistive device [12, 34, 43]. For instance, older people incline to switch off false alarm by themselves. In addition, cost of assistive device and maintenance charges are of a great concern to older adults. This makes them decline acceptance of expensive assistive devices [23, 24, 47, 64]. One more observation is older people favor attractive and dainty devices created in different colors [37]. Additionally, findings of this research show that it is difficult for them to press the button of device and read the gray color text and background [37]. Older adults encountered less hardship to wear wrist devices; therefore, this type of device design impressed them substantially [37]. Brownsell and Hawley [14] indicate that ICT devices empower elderly to feel independent and safe to take risk.

**Conclusion**

All in all, various assistive medical robots and devices are designed and developed for growing population of older adults. Although there are common needs and preferences among different segment of older adults, it should be considered that each segment has its specific needs and preferences. Consequently, it is substantial to develop the right assistive robot or device for them. Apart from needs and preferences of older adults, cost of robot or device is a primary factor in acceptance and adoption. Proper management of production cost and design of a sound sale strategy are of great importance in this regard. Research, discovering needs and preferences of elderly from assistive medical robots and devices has paved the ground for researchers and scholars to design robots and devices fulfilling their needs and expectations. Findings around acceptance of assistive devices from older adults’ perspectives should be on top of the data necessary to inform the design and development process. Furthermore, understanding their attitudes while dealing with, approaching by, or having interaction with assistive robots is of great importance to inform the designers, developers, and programmers.

**Authors’ contributions**

KMG initiated the project topic. This project will investigate the assessment of assistive medical robots from older adults’ perspectives with the purpose of identifying older adults’ needs, expectations, and preferences. The findings of this particular research project will inform robot designers, developers, and programmers to come up with robots fulfilling elderly’s needs while improving their life quality. He revised the draft written by NM. KMG added significant sections around the paper contribution and conclusion. NM reviewed relevant contribution to this research and compiled the paper. All authors read and approved the final manuscript.

**Author details**

1 School of Life & Health Sciences, Aston University, Aston Triangle, Birmingham B4 7ET, UK. 2 Department of Land Management and Systems, Faculty of Agribusiness and Commerce, Lincoln University, PO Box 85084, Lincoln 7647, Christchurch, New Zealand. 3 Department of Mechanical Engineering, Auckland University of Technology, SS Wellesley St, Auckland 1010, New Zealand.

**Acknowledgements**

The authors of this paper would like to thank Lincoln University in New Zealand for offering the funding support for this publication.

**Competing interests**

The authors declare that they have no competing interests.

**Funding**

This research is originally funded by research grant from Lincoln University, New Zealand.

**Publisher’s Note**

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

**Received:** 26 October 2016  **Accepted:** 8 September 2017

**Published online:** 20 September 2017

**References**

1. Alaiad A, Zhou L. The determinants of home healthcare robots adoption: an empirical investigation. Int J Med Inform. 2014;83(11):825–40.
2. Alami R, Sidobre D. A mobile manipulator robot that brings objects to assist people. Gerontechnology. 2014;13(2):78–9.
3. Anderson MD. U.S. Patent No. 7,938,413. Washington, DC: U.S. Patent and Trademark Office; 2011.
4. Arras KO, Cerqui D. Do we want to share our lives and bodies with robots? A 2000 people survey (No. LSA-REPORT-2005-002); 2005.
5. Ball MM, Perkins MM, Whitington FJ, Hollingsworth C, King SV, Combs BL. Independence in assisted living. J Aging Stud. 2004;18(4):467–83.
6. Banks MR, Willoughby LM, Banks WA. Animal-assisted therapy and loneliness in nursing homes: use of robotic versus living dogs. J Am Med Dir Assoc. 2008;9(3):173–7.
7. Bateni H, Maki BE. Assistive devices for balance and mobility: benefits, demands, and adverse consequences. Arch Phys Med Rehabil. 2005;86(1):134–45.
8. Bateni H, Bateni BE. Assistive devices for balance and mobility: benefits, demands, and adverse consequences. Arch Phys Med Rehabil. 2005;86(1):134–45.

9. Bayer E. Innovations in reducing preventable hospital admissions, readmissions, and emergency room use: an update on health plan initiatives to address national health care priorities. AHP Center for Policy and Research, 2010.

10. Beer JM, Takayama L. Mobile remote presence systems for older adults: acceptance, benefits, and concerns. In: Proceedings of the 6th international conference on human–robot interaction. ACM, 2011. p. 19–26.

11. Bemelmans R, Gelderblom JG, Jonker P, De Witte L. Socially assistive robots in elderly care: a systematic review into effects and effectiveness. J Am Med Dir Assoc. 2012;13(2):114–20.

12. Blythe MA, Monk AF, Doughty K. Socially dependable design: the challenge of ageing populations for HCI. Interact Comput. 2005;17(6):672–89.

13. Broadbent E, Tamagawa R, Patience A, Knock B, Kensey N, Day K, MacDonald BA. Attitudes towards health-care robots in a retirement village. Australas J Ageing. 2012;31(2):115–20.

14. Brownsell S, Hawley MS. Automatic fall detectors and the fear of falling. J Telemed Telecare. 2004;10(5):262–6.

15. Caine KE, Fisk AD, Rogers WA. More than a servant: self-reported willingness of younger and older adults to having a robot perform interactive and critical tasks in the home. In: Proceedings of the human factors and ergonomics society annual meeting. 2007. p. 1–5.

16. Cesta A, Cottrellas G, Giuliani V, Pecora F, Scopelliti M, Tiberio L. Psychological implications of domestic assistive technology for the elderly. PsycholNol. 2007;5(3):229–52.

17. Charness N, Boot WR. Aging and information technology use potential and barriers. Curr Dir Psychol Sci. 2009;18(5):253–8.

18. Chou HK, Yan SH, Lin IC, Tsai MT, Chen CC, Wong LC. A pilot study of the telecare medical support system as an intervention in dementia care: the views and experiences of primary caregivers. J Nurs Res. 2012;20(3):169–80.

19. Coughlin JF, Pope JE, Leedle BR. Old age, new technology, and future innovations in disease management and home health care. Home Health Care Manag Pract. 2006;18(3):196–207.

20. Czaja SJ, Charness N, Fisk AD, Hertzog C, Nair SN, Rogers WA, Sharit J. Factors predicting the use of technology: findings from the Center for Research and Education on Aging and Technology Enhancement (CREATE). Psychol Aging. 2006;21(2):333.

21. Dahl TS, Boulos MNK. Robots in health and social care: a complementary technology to home care and telehealthcare? Robotics. 2013;3(1):1–21.

22. Davis FD. Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Q. 1989;13(3):319–40.

23. Demiris G, Rantz MJ, Auer SK, Herrin J, Stockton NM. Development of a multidisciplinary collaboration for socially assistive robotics. In: AAAI workshop on pervasive computing technologies for healthcare. IEEE, 2010. p. 1–8.

24. Demiris G, Rantz MJ, Aud MA, Marek KD, Trierwiler HW, Skubic M, Hussam AA. Service robots in elderly care at home: perceptions of information technology use. Generations. 1996;19:41–6.

25. Dijkstra N, Boot WR, Struyf F. Mobile remote presence systems for older adults: acceptance, benefits, and concerns. In: Proceedings of the 6th international conference on human–robot interaction. ACM, 2011. p. 19–26.

26. Forlizzi J. How robotic products become social products: an ethno–critical task in the home. In: Proceedings of the human factors and ergonomics society annual meeting; 2007. p. 1–5.

27. Gitlin LN. Why older persons accept assistive technology or abandon its use. Generations. 1996;19:41–6.

28. Giuliani MV, Scopelliti M, Fornara F. Elderly people at home: technological help in everyday activities. In: ROMAN 2005. IEEE international workshop on robot and human interactive communication, 2005. IEEE, 2005. p. 365–70.

29. Graafmans WC, Lips PTAM, Wijhuizen GJ, Pluijm SM, Bouter LM. Daily physical activity and the use of a walking aid in relation to falls in elderly people in a residential care setting. Zeitschrift für Gerontologie und Geriatrie. 2003;36(3):123–8.

30. Hassmiller SB, Cozine M. Addressing the nurse shortage to improve the quality of patient care. Health Aff. 2006;25(1):268–74.

31. Hawley-Hague H, Boulton E, Hall A, Pfeiffer K, Todd C. Older adults' perceptions of technologies aimed at falls prevention, detection or monitoring: a systematic review. Int J Med Inform. 2014;83(6):416–26.

32. Heart T, Kalderon E. Older adults: are they ready to adopt health-related technologies? Int J Med Inform. 2013;82(1):209–31.

33. Heerink M, Klöse B, Evers V, Wielinga B. Assessing acceptance of assistive social agent technology by older adults: the Almere model. Int J Soc Robot. 2010;2(4):361–75.

34. Heinbuchner B, Hautzinger M, Becker C, Pfeiffer K. Satisfaction and use of personal emergency response systems. Zeitschrift für Gerontologie und Geriatrie. 2010;43(4):219–27.

35. Helal A, Abdulkarazak B. TecCarRob. tele-care using telepresence and robotic technology for assisting people with special needs. Int J ARM. 2006;7(3):46–53.

36. Hewson DJ, Gutierrez Ruz C, Michel H. Development of a multidimensional evaluation method for the use of a robotic companion as a function of care relationships. Gerontechnology. 2014;13(2):79.

37. Holzinger A, Seale G, Prückner S, Steinbach-Nordmann S, Kleinberger T, Hirt E. Tennenm J. Perceived usefulness among elderly people: experiences and lessons learned during the evaluation of a wrist device. In: Proceedings of the 6th international conference on pervasive computing technologies for healthcare. IEEE, 2010. p. 1–5.

38. Horton K. Falls in older people: the place of telemonitoring in rehabilitation. J Rehabil Res Dev. 2006;39(4):143–52.

39. Jay GM, Willis SL. Influence of direct computer experience on older adults’ attitudes toward computers. J Gerontol. 1992;47(4):P250–7.

40. Joyce BM, Kirby RL. Canes, crutches and walkers. Am Fam Physician. 1991;43(2):535–42.

41. Klamer T, Allouch SB. Acceptance and use of a social robot by elderly users in a domestic environment. In: Proceedings of the 6th international conference on pervasive computing technologies for healthcare. IEEE, 2010. p. 1–8.

42. Lindemann U, Schwenk M, Klenk J, Kessler M, Weyrich M, Kurz F, Becker C. Problems of older persons using a wheeled walker. Aging Clin Exp Res. 2016;28(2):215–20.

43. Londie ST, Rousseau J, Ducharme F, St-Arnaud A, Meunier J, Saint-Arnaud J, Giroux F. An intelligent video monitoring system for fall detection at home: perceptions of elderly people. J Telemed Telecare. 2009;15(8):383–90.

44. Marrison B, Gelin R, Koudelkova Delimorges P. Humanoid robots for elderly autonomy. Gerontechnology. 2014;13(2):77–8.

45. Mellenhorst AS, Rogers WA, Bouwhuys DG. Older adults’ motivated choice for technological innovation: evidence for benefit-driven selectivity. Psychol Aging. 2006;21(1):190.

46. Michaël F, Boissy P, LaBonte D, Cornuejols H, Grant A, Lauria M, et al. Telepresence robot for home care assistance. In: AAMIA spring symposium: multidisciplinary collaboration for socially assistive robotics, 2007. p. 50–5.

47. Mihalidis A, Cockburn A, Longley C, Boger J. The acceptability of home monitoring technology among community-dwelling older adults and baby boomers. Assist Technol. 2008;20(1):1–12.

48. Miticzer TL, Chen TL, Kemp CC, Rogers WA. Identifying the potential for robotics to assist older adults in different living environments. Int J Soc Robot. 2016;201(21):213–27.

49. Morris A, Goodman J, Brading H. Internet use and non-use: views of older users. Univ Access Inf Soc. 2007;6(1):43–57.

50. Ozguler A, Loeb T, Baaër M. Maintaining elderly people at home with a telemedicine platform solution: the QuoVAIDIS project. Gerontechnology. 2014;13(2):80.

51. Pain H, Gale CR, Watson C, Cox V, Cooper C, Sayer AA. Readiness of elders to use assistive devices to maintain their independence in the home. Age Ageing. 2007;36(4):465–7.

52. Parker MG, Thorlund M. Health trends in the elderly population: getting better and getting worse. The Gerontologist. 2007;47(2):150–8.

53. Piagni L, Facal D, Blasi L, Andrich R. Service robots in elderly care at home: users’ needs and perceptions as a basis for concept development. Technol Disabil. 2012;24(4):303–11.

54. Rentschler AJ, Cooper RA, Blasch B, Boninger ML. Intelligent walkers for robotic technology for assisting people with special needs. Int J ARM. 2006;7(3):46–53.

55. Pollack MB, Brown L, Colby D, Orzco C, Peintner B, Ramakrishnan S, et al. Pearl: a mobile robotic assistant for the elderly. In: AAAI workshop on automation as eldercare, vol. 2002. p. 85–91.
56. Rogers WA, Mynatt ED. How can technology contribute to the quality of life of older adults. The technology of humanity: can technology contribute to the quality of life. 2003; 22–30.

57. Salminen AL, Brandt Å, Samuelsson K, Töytäri O, Malmivaara A. Mobility devices to promote activity and participation: a systematic review. J Rehabil Med. 2009;41(9):697–706.

58. Scopelliti M, Giuliani MV, Fornara F. Robots in a domestic setting: a psychological approach. Univ Access Inf Soc. 2005;4(2):146–55.

59. Shariat J, Czaja SJ, Perdomo D, Lee CC. A cost-benefit analysis methodology for assessing product adoption by older user populations. Appl Ergon. 2004;35(2):81–92.

60. Smarr CA, Prakash A, Beer JM, Mitzner TL, Kemp CC, Rogers WA. Older adults’ preferences for and acceptance of robot assistance for everyday living tasks. In: Proceedings of the human factors and ergonomics society annual meeting, vol. 56, no. 1. SAGE Publications; 2012. p. 153–7.

61. Smarr C, Fausset CB, Rogers WA. Understanding the potential for robot assistance for older adults in the home environment. Atlanta: Georgia Institute of Technology; 2011.

62. Stafford RQ, Broadbent E, Jayawardena C, Unger U, Kuo IH, Igic A, et al. Improved robot attitudes and emotions at a retirement home after meeting a robot. In: 19th International symposium in robot and human interactive communication. IEEE, 2010. p. 82–7.

63. Stafford RQ, MacDonald BA, Jayawardena C, Wegner DM, Broadbent E. Does the robot have a mind? Mind perception and attitudes towards robots predict use of an eldercare robot. Int J Soc Robot. 2014;6(1):17–32.

64. Steele R, Lo A, Secombe C, Wong YK. Elderly persons’ perception and acceptance of using wireless sensor networks to assist healthcare. Int J Med Inform. 2009;78(12):788–801.

65. Tinker A, Lansley P. Introducing assistive technology into the existing homes of older people: feasibility, acceptability, costs and outcomes. J Telemed Telecare. 2005;11(suppl 1):1–3.

66. Van Hoof J, Kort HSM, Rutten PGS, Duijnstee MSH. Ageing-in-place with the use of ambient intelligence technology: perspectives of older users. Int J Med Inform. 2011;80(5):310–31.

67. Van Riel KMM, Hartholt KA, Panneman MJM, Patka P, van Beeck EF, van der Cammen TJ. Four-wheeled walker related injuries in older adults in the Netherlands. Inj Prev. 2014;20(1):11–5.

68. Vannich Schip JS. U.S. Patent No. 6,688,633. Washington, DC: U.S. Patent and Trademark Office; 2004.

69. Wilkinson KA. U.S. Patent No. 4,899,771. Washington, DC: U.S. Patent and Trademark Office; 1990.

70. Wada K, Shibata T. Living with seal robots—its sociopsychological and physiological influences on the elderly at a care house. IEEE Trans Robot. 2007;23(5):972–80.

71. Wada K, Shibata T, Musha T, Kimura S. Robot therapy for elders affected by dementia. IEEE Eng Med Biol Mag. 2008;27(4):53–60.

72. Wu YH, Wrobel J, Cormuet M, Kerhervé H, Dammée S, Rigaud AS. Acceptance of an assistive robot in older adults: a mixed-method study of human–robot interaction over a 1-month period in the Living Lab setting. Clin Interv Aging. 2014;9:801–11.

73. Yampolskiy RV. Artificial intelligence safety engineering: Why machine ethics is a wrong approach. Berlin: Springer; 2013. p. 389–96.