Socially Assistive Robots

Subjects: Robotics

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Socially assistive robots (SARs) have been used to help to mitigate the effects of the pandemic on older adults, including loneliness and isolation, and to alleviate the workload of both formal and informal caregivers. We identify the specific applications of SARs during the pandemic to help the older population and their caregivers. The robots all have multimodal communication abilities, and were able to perform multiple functions, including: (1) health monitoring (routinely checking vital signs and alerting healthcare professionals of any abnormalities), (2) screening of visitors (checking for masks and measuring temperature upon entering facilities), (3) social facilitation (enabling video communication between residents and families or healthcare staff), (4) activity facilitation (singing, dancing), (5) providing information and reminders for tasks (weather and food menu, scheduled activities), and (6) cognitive and physical training activities (memory games, exercises). Physical characteristics of the robots are outlined, including: height, presence of touchscreen tablet, facial recognition, natural language processing.

socially assistive robots | older adults | health and eldercare | human–robot interaction | COVID-19 pandemic

1. Introduction

The world's population is aging, which is placing a strain on caregivers to support and care for the elderly as they age. By 2030, it is predicted that there will be a worldwide shortage of more than 100,000 caregivers [1]. For the first time in history, the number of people older than 64 years old in the world has surpassed those younger than 5 years old [2]. By 2050, the share of the global population older than 65 is expected to rise to 16%, from 9.3% in 2020 [3].

With the advent of the COVID-19 pandemic, opportunities for social relationships, especially for older adults, have decreased. Social isolation and loneliness have spiked worldwide [4][5], threatening well-being and representing a major determinant of health, including the increased risk of premature death [6]. The prevalence of loneliness among older adults living in long-term care is at least double that of those living in communities; during the pandemic, residents were isolated from visitors to reduce the risk of spreading the virus, and group activities and communal dining were halted, which in turn increased isolation and loneliness among residents [7]. The pandemic offers a "unique opportunity to envision, pilot or implement novel technological solutions that could have a lasting impact on the health and well-being of older adults" [8]. Socially assistive robots (SARs) can be used to provide a safe means of interaction for older people. They can also be easily sanitized regularly. These interactive robots behave in a lifelike manner, they can recognize and interpret verbal and non-verbal communication modes such as

speech, gestures, and eye contact, and respond appropriately using their own sophisticated emotional intelligence and conversation abilities [6].

Data on mental health repercussions from the 2003 Severe Acute Respiratory Syndrome outbreak indicated that stress, social disengagement, and anxiety led to a number of unfortunate deaths by suicide among the elderly [9] [10]. The COVID-19 outbreak is of particular concern in hospitals and healthcare facilities, as many long-term care facilities went into lockdown, restricting visitors and family members from seeing and interacting with residents. The psychological impacts of quarantine on the elderly and on healthcare workers, such as confusion, fear, anger, grief, and anxiety, can be long-lasting [11]. The age-related case fatality rate of COVID-19 in people over 80 years old is at 14.8%, with the most serious cases found in people with comorbid conditions [12]. In Canada, COVID-19 resulted in a significantly disproportionate number of outbreaks and deaths in both long-term care and retirement homes [13]. During previous pandemics, such as Severe Acute Respiratory Syndrome, Ebola, and avian flu, robotics were used to mitigate the risk to healthcare workers, by serving as telepresence communication systems and performing clinical activities, such as the delivery of medication and meals, and transporting bio-hazardous materials [14]. Placing robots in healthcare facilities can help to lower staff workload, thereby increasing the overall efficiency of these facilities [12] and minimizing the impact on residents.

When using SARs together with general information communication technologies (ICT), pre-COVID-19 studies showed that depression can be reduced, through engaging seniors in daily interactions with a robot [15]. Robotics has also been used to increase independent living, help reduce social isolation and enhance well-being by increasing social connectedness. The uptake of assistive technologies, such as robotics, sensors, computers and the Internet, by older adults was shown to have a positive impact not only on the individuals, but also on those who take care of them, such as healthcare professionals and family members [15].

The COVID-19 pandemic is showing that humans and robots can work together to keep people safe; technology has not replaced in-person care, but rather reduced the number of times healthcare staff had to be in direct contact with residents [16].

2. Crisis in Long-Term Care Homes/Hospitals

In this section, we investigate Research Question 1: What are the impacts of the pandemic on the needs of older adults and their caregivers? Namely, we explore the crisis that the COVID-19 pandemic has brought about in long-term care homes and hospitals.

For example, the proportion of COVID-19 deaths in long-term care and retirement residences alone represents 69% of Canada's overall COVID-19 deaths, significantly higher than the international average of 41% [13]. In the US, more than 40% of the documented deaths due to COVID-19 have been nursing home residents [17][18]. Over 50% of all nursing homes in the U.S. were already hit by COVID-19 by winter 2020, with about one in five nursing home residents with COVID-19 dying from the illness [19]. Some European countries such as France and Ireland have reported that 50% of the deaths have been residents of nursing homes [20][21].

Institutional care suffers from regulatory neglect, low staff to resident ratios, as well as low wages for front-line staff, high turnover rate among employees, and part-time employees who work in multiple homes and get no paid sick leave. All of these factors contribute to creating environments with minimal resilience to adverse events. Evidence on how this crisis can be addressed includes relationship-centered solutions, integrated health and social care, and telehealth [20][21]. SARs, being resilient to future outbreaks, and providing ways for residents of long-term care homes to keep in contact with healthcare providers and family members, can be part of the solution. In a study conducted in nursing homes in Japan, it was found that the adoption of robots decreased difficulty in staff retention, and that robots can be used to meet the challenges imposed by a rapidly aging population [22].

In Japan, about 60% of nursing homes currently use SARs, including during the COVID-19 pandemic, and of the nursing homes that adopted robots, there were 8–11% more staff than at nursing homes that did not adopt robots [23]. The robot type that has the highest rate of adoption is a monitoring robot that is used to alert nurses or caregivers if there is any abnormal activity, especially during the night when there are fewer staff available. This is a real example of robots not replacing care workers, but supplementing them, allowing for critical personnel to focus more on patient care, and thereby increasing the quality of care [23].

Older adults have also increased their use of technology, such as making video calls to stay in touch with family and friends during the pandemic [24]. Expanding tech literacy is a new skill that will likely stay with the elderly after lockdowns have been lifted [25].

People with Dementia Coping with COVID-19

Social distancing and self-isolation are disrupting routine and regular support systems for the elderly. This is particularly concerning for residents with dementia, since strategies normally used to manage dementia symptoms, such as distraction, stimulation, and social interaction, have been limited [26]. Dementia can worsen under stress, especially with changes to daily routines [27].

A telephone survey conducted during the first month of the lockdown in April 2020 with 139 participants attending the Center for Cognitive Disturbances and Dementia, at Sapienza University of Rome (Italy), who were either living with mild cognitive deficits or were caregivers of people with dementia, found that one third of those surveyed had worsening cognitive symptoms (memory and orientation abilities) as well as a reduced level of independence in personal care and housekeeping [26]. More than half of the respondents experienced agitation/aggression, apathy, and depression. It is particularly worth noting that half of the caregivers reported higher levels of stress and exhaustion. It was concluded that alternative forms of support, such as technological support, are urgently needed [26].

In a study conducted in Korea between September 2018 and February 2020, just before the onset of the pandemic, 24 participants with mild cognitive impairment used the robot Bomy, a small personal care robot equipped with cognitive training games, in their homes for four weeks [28]. The robot encouraged participation in scheduled cognitive training programs, and alerted designated caregivers if participation was lacking. It was found

that working memory improved when people with mild cognitive impairment used the personal care robot in their homes for cognitive intervention [28]. The robot seal Paro has also been shown to help reduce stress and minimize feelings of isolation and despair among people with dementia [29][30]. In general, SARs have shown promise in helping people with dementia by providing companionship [31], cognitive and social stimulation [32][33], and assistance with activities of daily living [34]. SARs hold specific promise to mitigate the impacts of COVID-19 by providing this population with complementary support to alleviate anxiety, irritability and agitation, loneliness and isolation, while improving engagement and reducing caregiver burden [31].

3. How Are Socially Assistive Robots Helping during COVID-19?

Robotic technology is one of the best resources for battling COVID-19 [35]. Robots are being used to move people out of high-risk situations, including: (1) to disinfect hospitals and urban streets, as mobile UV or spraying robots [36], (2) to prepare orders, stock shelves and fulfill orders at retail stores, warehouses, and perform inventory checks [37], and (3) the delivery of groceries, food, and other products [38][39]. For example, robots are also being used for meal delivery to those in quarantine, including monitoring to check that people are following quarantine enforcement [40], advising people to maintain social distancing [41], and autonomously delivering supplies, such as water or medication to dedicated spots in hospital rooms, or by delivering blood samples to the lab for analysis [42].

Robots can be equipped with infrared (IR) sensors or non-contact thermometers to evaluate temperature in a contactless way [43], and RGB cameras to measure breathing rate, pulse rate, and blood oxygen saturation [44]. Some hospitals are operating with fewer staff numbers to try to minimize the exposure of their workforce to the virus; therefore, it is essential for staff to focus their time on patient/resident care rather than on repetitive tasks, such as enforcing face mask and social distancing rules, and spraying disinfectant [45]. SARs can perform these repetitive tasks and reduce unnecessary contact between healthcare workers and residents in long-term care to keep vulnerable older adults safe.

In a worldwide study that looked at SAR implementation at large in society during the pandemic (between March–June 2020), three main roles were identified for these types of robots: (1) a liaison in tasks that require human–human interaction such as monitoring and social interaction, (2) a safeguard, implementing protective measures against the virus, to ensure a contagion risk-free environment, and (3) a well-being coach, which includes providing entertainment for quarantined patients and residents, medical and well-being adherence, and the promotion of physical exercise [46]. Robot functions associated with the roles of liaison and safeguard are now more visible due to the pandemic: SARs acting as safeguards help to enforce COVID-19 protective measures by detecting and ensuring that people are wearing masks or maintaining the required physical distances. They have also been equipped with technologies for surface disinfection. This study highlights the increase in the relevance of the liaison and safeguard robot functions due to the pandemic's demands of physical distancing and isolation. However, there is a need for well-being robot coaches to provide more effective psychological aid to people in isolation during the pandemic [46]. These robots can, for example, initiate conversations to address concerns about the virus when the

older person is feeling anxious, since these types of functions have rarely been specifically adapted for a pandemic situation.

3.1. Socially Assistive Robots Used during COVID-19

In this section, we investigate Research Question 2: Which SARs were deployed during the pandemic for this vulnerable demographic? Herein, we discuss commercially available SARs used during the COVID-19 pandemic with older adults. A major limitation during the pandemic was that few research robots (or robots under development) were able to be deployed in long-term care homes, due to lockdowns and restrictions. We, therefore, focused our survey on commercially available SARs. In the future, we anticipate seeing more HRI research as facilities open up again. Furthermore, in this section, we investigate Research Question 3: What type of help and tasks did the robots provide older adults and their caregivers? We identify the specific applications of SARs during the pandemic to help the older population and their caregivers. A summary of the commercially available robots, along with their main functions during the pandemic, is provided in **Table 1**. The robots all have multimodal communication abilities, and were able to perform multiple functions, including: (1) health monitoring (routinely checking vital signs and alerting healthcare professionals of any abnormalities), (2) screening of visitors (checking for masks and measuring temperature upon entering facilities), (3) social facilitation (enabling video communication between residents and families or healthcare staff), (4) activity facilitation (singing, dancing), (5) providing information and reminders for tasks (weather and food menu, scheduled activities), and (6) cognitive and physical training activities (memory games, exercises).

Table 1. Summary of surveyed commercial socially assistive robots (SARs) deployed during the COVID-19 pandemic with older adults.

Robot Name, Company/Developer	Main Features	Environment/Location	Function during the COVID-19 Pandemic	Reference
Pepper, by Softbank Robotics  Reprinted with permission from ASBLab, University of Toronto. 2021	1.2 m-tall mobile humanoid robot with two arms, a head, and a torso with a touchscreen tablet Facial and mask recognition, natural language processing	Deployed in hospitals, elderly care homes. Japan, France, Britain	Health monitoring Screening Activity facilitation Providing information Cognitive and physical training	[47][48]

Robot Name, Company/Developer	Main Features	Environment/Location	Function during the COVID-19 Pandemic	Reference
Temi, by Robotemi  Reprinted with permission from Robotemi. 2021	1 m-tall mobile robot, with a touchscreen tablet for a head Facial recognition, natural language processing	Deployed in hospitals, elderly care homes. Israel, Germany, United States, China, South Korea, Hong Kong	Health monitoring Screening Social facilitation	[49][50]
Sanbot Elf, by Qihan Technology  Reprinted with permission from SARA Robotics. 2021	1 m-tall mobile robot with two arms, a head, and a torso with a touchscreen tablet Facial and speech recognition	Deployed in elderly care homes and hospitals. Netherlands, Italy	Health monitoring Social facilitation Activity facilitation Providing information, and reminding of tasks	[51]
Lio, by F&P Robotics  Reprinted with permission from F&P Robotics. 2021	1 m-tall mobile robot with a non-touch display on its base, and one 6-degree-of-freedom (DoF) robotic arm Facial and speech recognition, Object manipulation	Deployed in elderly care homes and hospitals. Switzerland, Germany	Health monitoring Activity facilitation Providing information, and reminding of tasks Physical training	[52][53]
James, by Zorabots  Reprinted with permission from Zorabots. 2021	1.2 m-tall mobile robot with a touchscreen tablet for a head Facial and speech recognition Tele-operation features Multi-robot coordination	Deployed in elderly care homes. Belgium	Health monitoring Social facilitation	[54][55]

Robot Name, Company/Developer [48]	Main Features	Environment/Location	Function during the COVID-19 Pandemic	Reference
ARI, by PAL Robotics  Reprinted with permission from PAL Robotics. 2021 [60]	1.65 m mobile humanoid robot with two arms, a head, and a torso with a touchscreen tablet Facial recognition, natural language processing Connects to other smart devices	Deployed in elderly care homes. [47] Spain, Italy, Greece, Ireland	Health monitoring Screening Activity facilitation Social facilitation Providing information, and reminding of tasks Cognitive and physical training	[56][57] [47]
Misty, by Misty Robotics [50]  Reprinted with permission from Misty Robotics. 2021 [50][61]	36 cm mobile robot with 2 arms Facial and speech recognition [49]	Deployed in homes of the elderly. United States, Spain [50][61]	Health monitoring Screening Activity facilitation Providing information and reminding of tasks	[58][59]

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using a 4D intelligent RF sensor developed by Vayyar Imaging. Then, in real time, the vital signs and COVID-19 infection risk level of a person will be determined and presented on the robot's screen [62]. Temi can conduct telepresence sessions through an integrated app, allowing residents in care homes to maintain their social networks during lockdowns and when limited visitors are allowed. In April 2020, Connected Living, a social impact company that serves senior living communities worldwide by providing technology solutions to create connected communities for seniors, partnered with Robotemi for the deployment of the robot. They are deploying the robots in Maplewood Senior Living, in the United States, to act as a companion and improve the well-being of the residents through social facilitation, such as by providing telehealth calls to residents or connecting remotely with family members, and to help stop the spread of COVID-19, by bringing hand sanitizer, asking residents to wash their hands, and taking temperature readings from visitors [63].

Sanbot Elf, by Qihan Technology, is a 1 m-tall mobile robot with two arms, a head, and a torso with a touchscreen tablet [64]. The robot has facial and speech recognition capabilities. The main benefits of this robot are that it can host a medical service platform developed by SARA Robotics that can cooperate with the medical care platforms of hospitals, and elderly care homes [65]. SARA Robotics has deployed this robot in twelve care facilities and hospitals in the Netherlands to improve quality of life and provide support to alleviate caregiver staffing shortages [51]. The robot acts as a support to elderly people suffering from dementia by providing cognitive and physical exercises, games, music therapy, and performing repetitive tasks, such as reminding staff and residents of upcoming events

[51]. SARA Robotics is planning to expand the functionalities of the robot, introducing autonomous navigation and home automation, where the robot will be able to detect falls using its cameras [66]. The SARA Home system allows caregivers to provide a personalized profile and health plan for every client. SARA Robotics is continuing to gather feedback from care facilities as to how to alleviate the work burden on health care professionals, and how to improve quality of life for residents. At the beginning of the pandemic, six Sanbot Elf robots were deployed in the Circolo Hospital in Varese, Italy, a region at the epicenter of the COVID-19 outbreak [67], where the robots helped to keep patients connected to healthcare staff through its video chat capabilities.

Lio, by F&P Robotics, is a 1 m-tall mobile robot with a non-touch display on its base and one six-degrees-of-freedom (DoF) robotic arm with manipulation capabilities [53]. Lio's main strengths are that it also has a multifunctional robotic arm with a gripper that can pick up small objects, such as water bottles, and transport them on its platform; the arm can also be used for disinfecting tasks [53]. It also has facial and speech recognition capabilities. During the COVID-19 pandemic, Lio has been adapted to perform disinfection tasks by grasping a UV-C light that it carries and placing it over the object to be disinfected. Lio can perform health monitoring by detecting people with an elevated body temperature using its IR camera placed on its gripper [52]. If an elevated temperature is detected, the robot alerts medical personnel. Lio has four embedded processing units, so data can be stored locally on the robot, without the need for cloud computing, to ensure data privacy. The robot can also perform physical activity facilitation, provide information and reminders of tasks [52][53].

James, by Zorabots, is a 1.2 m-tall mobile robot with a touchscreen tablet for a head [55]. James has facial and speech recognition capabilities. The robot is being used in elderly care homes in Belgium during the COVID-19 pandemic to help residents keep in contact with family and loved ones through video calls on its tablet [54][68]. Its main strengths are that it incorporates the Zora software application that can be used to control and coordinate multiple James robots; it also lets a user tele-operate the robot via local network or cloud connection [69]. The James robot is part of ReMember-Me, a smart system deployed across countries in Europe and Latin America which aids in the prevention and detection of cognitive decline among older adults [70]. The robot monitors a person's health status, and engages the elderly in personalized cognitive activities, as well as promotes social inclusion among older adults [70]. The system includes sleep, activity, and mood assessment, short daily exercises, and socialization [70].

ARI, by Pal Robotics, is a 1.65 m-tall mobile humanoid robot with two arms, a head, and a torso with a touchscreen tablet [57]. ARI is able to communicate via natural language processing, and has object and face recognition [57]. Its main benefits are that it can display multimodal behavior through gaze direction, speech, and gestures to directly interact with people in bi-directional communication. ARI can also connect with other smart devices, wearable sensors, and applications to monitor the health and well-being of older adults [56]. Due to the pandemic, ARI has been modified to include an IR camera in its head to detect temperature. In spring and summer of 2021, ARI will be taking part in several pilot projects with older people living in their own homes, or in residential care homes, in Spain, Italy, Greece, and Ireland. Pilot 1 consisted of four to five participants between 70 and 80 years old over a four week period, at Clinica Humana in Mallorca, Spain in May 2021 [71][72]. ARI was deployed to detect temperature, provide reminders, entertain and connect to others through video calls. The next pilot will be in

residential homes, where ARI will act as a companion robot, and with the help of a psychologist, will be used as a complementary tool to promote engagement in cognitive games such as Tic-Tac-Toe [71][72].

Misty, by Misty Robotics, is a 36 cm-tall mobile robot with two arms [59]. Misty has facial and speech recognition capabilities. During the pandemic, the robot has been integrated with an IR camera in its visor, and can be equipped with UV lamps for disinfection [73]. In addition to non-contact temperature sensing, the robot can ask health screening questions [58]. The results are recorded and available through an admin portal, and texted or emailed to designated care personnel, which is an asset of this robot [58]. In Spain, Misty is being used to augment the abilities of human care providers whose job it was to visit those aging-in-place in their own homes, by allowing them to remotely check in more frequently than what is possible with home visits, even with pandemic quarantining regulations. Misty keeps track of the health of the elderly through asking them questions about daily habits such as sleep quality, medication taking, and diet [74]. Another of its strengths is that Misty also helps address loneliness in the elderly by providing companionship through dancing, telling jokes, and playing music.

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