

ORIGINAL ARTICLES

Assistive Robots Designed for Eldery Care and Caregivers

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ABSTRACT

As per the World Population prospects (19th revision), in 2019 every 11th person (11% of the population) was aged 65 or older and by 2050 every 6th person (16% of the world population) will be aged 65 or older. This rapid growth in people aged 65 and above has and will continue to pose some health management concerns, especially in the elderly with chronic ailments. The need for care provision for the elderly has provoked an exploration of various solutions to address elderly care management. Non-pharmacological interventions that utilize technology, such as robotics, are solutions that have proven to prolong independence and delay the admission of elderly into assisted care facilities. This paper will explore the various types of robotic solutions that are currently available to offer elderly care. This study will look at robotic solutions that are humanoid, animal-like, and robots that do not resemble humans or animals and their applications in elderly care. The various applications of robotics and the respective types of robots utilized in the provision of care in elderly care will be discussed as well.

Key Words: Assistive robots, Elderly care, Dementia, Humanoid robots, Non-pharmacological interventions

1. INTRODUCTION

The papers reviewed for this literature were published from 1995 to the current. This literature review used keywords such as humanoid robots, non-humanoid robots, assistive robotic designs, elderly care, and caregiver burden to perform the search. The search then narrowed down to include more detailed keywords including robotics in terms of cognitive improvement, companionship, living assistance, household assistance, navigation, exercise, home monitoring, feeding, lifting, medication management, and virtual presence. The search was narrowed down to a range of publication years between 1995 and 2021. This 26 year difference demonstrates the wide array of robotic design developments in elderly care management and subsequent caregiver assistance. The

narrowed search offered a collection of research that looks at numerous studies that focused on how robotics can be influential in promoting current deficiencies in elderly care and caregiver burden. The designs of the various robotics are explored through humanoid and non-humanoid robots.

The driving force behind America's increasing population age is largely due to the baby boomer generation. All baby boomers will be at the age of 65 by the year 2030. Based on this statistic, older Americans will comprise 21 percent of the population. Furthermore, nearly one in four Americans will be 65 years or older, the number of people 85 years or older will triple, and the country will add a half-million centenarians by 2060.^[1] With the dramatic rise of the elderly

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population, the demand for healthcare, at-home caregiving, and assisted living facilities increases. Many older adults will experience one or more chronic conditions, disabilities, or diseases that will need management to maintain independent living. The Journal of the American Medical Association discusses the preparation needed for better health and health care for an aging population. One vital direction Rowe et al., (2016) mentioned was to develop new models of care delivery that will broadly disseminate to address the clinical and financial challenges presented by impaired frail individuals.^[2] It is important to consider that long-term health management consists of both the individual's physical and mental health. The current health intervention for older people is to solely treat their condition from a medical perspective. Tkatch et al., (2016) reported that there is little emphasis on the subjective or psychosocial components of health. Population health management programs have yet to be strategically implemented into successful aging initiatives for older people.^[3] A new method of healthcare management will be needed to move beyond simple clinical intervention to a more comprehensive approach that will encompass the psychosocial aspect of health. This multidisciplinary approach may help older individuals promote an independent, and high quality of life.

Similar to other industries, the healthcare industry for the elderly demands a new approach to providing health services called automation of elderly care.^[4] This new approach is assumed to facilitate the burden of caregivers as well as to improve the quality of life of elderly people.^[4,5] Recently, using technologies such as robots has become more popular due to the increase in healthcare costs, the rising elderly population, and the lack of caretakers.^[4,6] In addition, some elderly prefer to live in their own house as much as possible, rather than living in nursing homes.^[5]

Assistive robots or service-type robots aim to promote or monitor the health situation of older people.^[7] As people age their physical and functional performance decline which decreases their mobility and increases the risk of fall and injury.^[7] Thus, the elderly need more support to continue their independent living.^[7,8] Assistive robots can help older people with their activities of daily living (ADLs) or instrumental activities of daily living (IADLs).^[7] ADLs are activities such as eating, walking,^[7] doing home chores,^[9] reminding everyday tasks and helping with performing those tasks, controlling individuals' mobility including navigation,^[8] being a companion,^[10] and monitoring older people who need care and attention continuously.^[6,8] IADLs include managing the home, shopping, and transportation.^[7] In addition, robotics can provide other healthcare benefits such as improvements in mood, loneliness, social interactions with others,^[11] and

interactive cognitive training.^[9] Robot therapy is now being considered a non-pharmaceutical therapy solution that can help people with dementia in order to reduce loneliness and agitation, and improve mood and social interaction.^[12] Together, the use of robotics can help the elderly regain a sense of independence. It may be beneficial to incorporate robots in a daily setting to provide physical assistance at an affordable cost. Just as it is important to consider physical care, elderly people may need monitoring. Active monitoring can track an individual and follow their health condition. This can be particularly useful in instances of elderly falls to prevent long-term health consequences.

The organization of this review paper will first explore the differences between humanoid and non-humanoid robots/animal-like robots that are used as assistive robots in elderly care. Following this, the paper will discuss the elderly care robots and their applications in promoting robotic care for the elderly and caregivers. The paper will discuss applications of robotics for the elderly, with a focus on how robotics can assist with cognitive improvement, companionship, grocery shopping, guidance and navigation, physical activity, and creating a smart home environment. The applications for caregivers will center on feeding assistance, laundry/garbage management, water delivery, lifting assistance, medication delivery, and providing a virtual presence for safe monitorization. Following this, the paper will discuss the pros and cons of various types of robots and their acceptability.

2. BACKGROUND

Robots that are designed to support older people and promote their quality of life are grouped into two categories: humanoid robots and non-humanoid robots. A third category of mechanical robots does not fit humanoid or non-humanoid robots.

The design of robots varies from fully automated, partially automated to fully controlled humanoid and non-humanoid robots.

- (1) Humanoid robots: A humanoid robot can be described as a robot that resembles a human in its appearance and interaction. These robots can be mobile, non-mobile, and projected. They usually have a head similar to a human face, a neck that allows multidirectional movement of the head, a torso that is equipped with a screen or tablet for communicating with the user, two arms, and may have legs/wheelbase. A humanoid robot usually is equipped with sensors allowing the robot to identify an obstacle, recognize humans and identify their emotions. The robot may follow or move toward

an object based on its mobility, and communicate with individuals through its speaker using natural language techniques.^[13] Robots can work in two modes, remotely controlled or autonomous, and are programmed to do specific activities.^[13] These types of robots can promote mobility;^[14] guide the elderly;^[14, 15] encourage physical activities;^[16] improve cognitive abilities through group activities, memory tests, or game playing;^[14, 17] or be used at smart houses in the configuration of an IoT solution. Some of the most popular humanoid robots are summarized in Table 1 of Appendix A.

(2) Non-humanoid robots/animal-like robots: Non-humanoid robots comprise of robots that do not look like humans. Some of these may look like animals, or have no resemblance to a living being. These types of robots, that sometimes are referred to as social robots are equipped with actuators, infrared sensors, stereoscopic vision, and hearing and touch sensors on the face, body parts, and tails that allow moving their body parts and expressing the emotion.^[8] These types of robots usually serve as companions and entertainment, reducing the sense of loneliness, offering emotional support, relaxing the elderly, and boosting their quality of life in general.^[6, 17, 18] Some of the most popular non-humanoid robots are listed in Table 2 of Appendix

A.

(3) Mechanical Robots: Mechanical robots are robots designed for a specific task and have no resemblance to any living being. This category of robots are used as an assistant to help older people with walking such as iGO, a smart walker robot^[19] or FriWalk, a walking assistant supporter^[20] or automated wheelchairs. These robots aim to increase the mobility of individuals by guiding them in indoor or outdoor environments along with the planned path.^[20] Some of them have a simple design like iGO, while other robots, like FriWalk, have a user interface consisting of a tablet that allows user interaction.^[20]

2.1 Application of Robots

Researchers define several applications for robots that cover both older people and caregivers' needs, such as social assistance and rehabilitation.^[21] Robots for rehabilitation purposes support elderly people physically, while social assistance robots can either be a social supporter or a service-provider.^[21] Figure 1 shows different applications for robots. Examples of social assistance robots are Paro, iCat, and iWalker, Pearl, Hobbit, PaPeRo, NAO, Kaspar, AIBO; and Care-O-bot, Handy-1, ISAC, My Spoon, HITOMI, PAM-AID.^[21, 22]

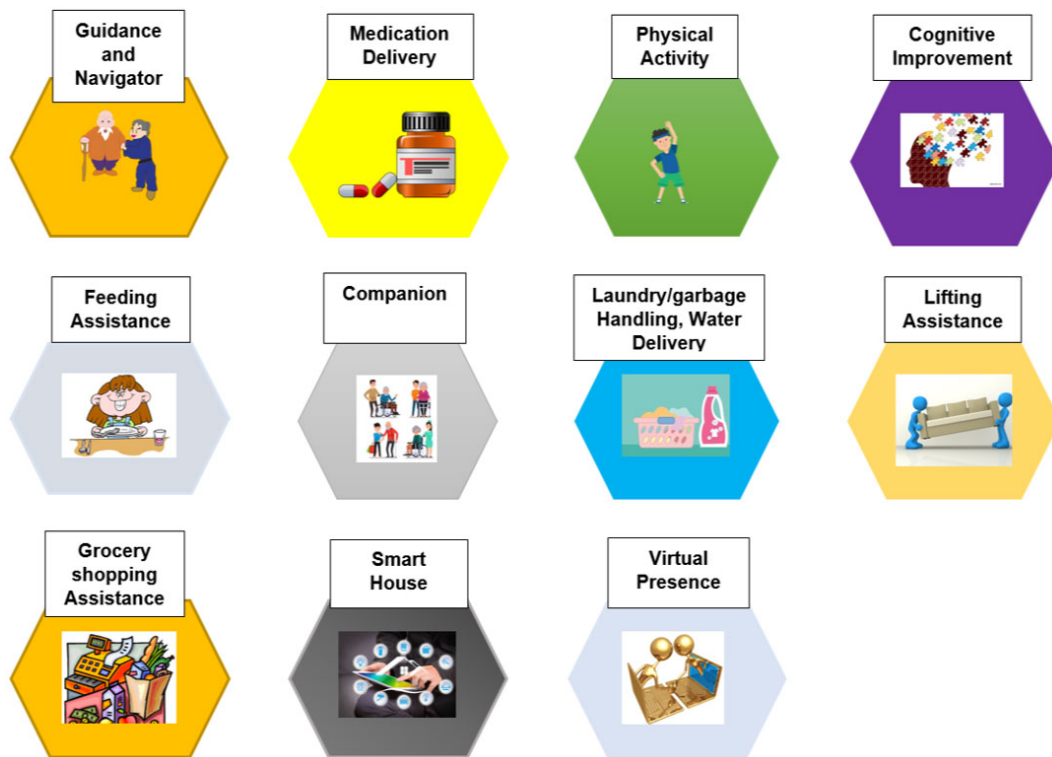


Figure 1. Robot application

2.1.1 Robots' Application for Elderly

Cognitive improvement Sometimes robots are used to exercise cognitive boosting activities such as game playing, image matching, and reminding daily activities. The incorporation of humanoid robots has been identified as a potential non-pharmaceutical therapy for mild cognitive impairment of older individuals.^[23] Pearl is one robot with the ability to act as a cognitive orthotic.^[14] The robot can function to remind seniors of daily routine activities, such as eating, drinking, bathroom use, and taking medication.^[14] The second goal of Pearl is to make decisions about what reminders to issue and when to issue them. The robot considers several factors such as ensuring the person knows the activity they are about to perform, making sure the person does the essential tasks like taking medications, avoiding annoying the person, and preventing the person from being over-reliant on the system.^[14] Another humanoid robot that has been used to address elderly cognition is NAO. In a study conducted by Pino et al., (2020), NAO was programmed to implement tasks from the memory-training program protocol. 21 participants (10F, 11M) were tested from the Center of Cognitive Disorders and Dementia of AUSL Parma. The results showed that memory training with NAO had an increase in visual gaze and reinforced therapeutic behavior. As a result, there was a reduction in depressive symptoms.^[23] NAO shows promise due to its highly engaging arrangement. Qualitative analysis reports that the majority of participants would like to have the robot in their own homes. This study may demonstrate the effectiveness of humanoid robots in a health care setting. And may further suggest a cost-effective implementation of technology in the health care system.^[23]

Companion A companion robot for older people is a robot that behaves socially and assists older adults.^[24] A companion robot is created for the sole purpose of providing companionship for people. The target population for these types of robots is the elderly and children. Several benefits have been discussed by the researchers using a companion robot. It can replace pet-therapy for people with allergies.^[24] In addition, pet-like robots can serve as a therapeutic tool. In robot therapy, these robots can stimulate people's knowledge and experience of animals through interaction with the robots and also further elicit their feelings when with the robot.^[25] Studies also show the efficiency of companion robots in boosting psychological symptoms of the elderly, reducing the stress level, and increasing social interaction.^[25] These robots try to increase the activity level of the elderly and enhance their well-being^[8] by walking and navigating them,^[4,8] entertaining them, and having intimate social reactions.^[4]

The appearance of the robot design is an important factor in

robot acceptance amongst older individuals.^[26] Companion robots are usually pet-like robots. The robotic design can thus play a crucial role in human-robot interactions. The Paro robot would be considered a therapeutic robot, specifically a mental commitment robot. Its purpose is to engender mental effects such as pleasure and relaxation to older individuals.^[25] Paro can provide non-verbal communication, which can be utilized to stimulate the human senses and extract associations. This can provide mental assistance to not only older people, but also those suffering from mild cognitive impairment. Aminuddin et al., (2016) created a study to evaluate the physical versus non-physical interactions with a switched on or a switched off Paro on participants' psychophysiological stress responses.^[27] It was found that an activated Paro was able to be more effective at reducing levels of stress, and improving moods compared to participants that interacted with the inactivated robot.^[27] Furthermore, the Paro robot has features to improve social interaction. This effect may be increased in the presence of caregivers or experimenters who are willing to participate in the interactions.^[28]

Grocery shopping assistance As aforementioned, one of the main objectives of designing assistive robots is to support the elderly with their everyday lives doing tasks such as moving around, transferring objects, and interacting with people.^[29] Shopping from big supermarkets and shopping centers is a big challenge for older adults. Several robots are designed for shopping purposes. These robots may be equipped with a basket that allows users to transfer the products around, speakers, and speech recognition algorithms to transfer the information to the user or the salesman.^[29] In general, grocery shopping assistant robots can boost the physical capability and quality of life of the users.^[29] Grocery shopping assistance is categorized into shopping cart assistants like CompaRob or in-store shopping assistant robots like Robovie, a humanoid robot.^[29]

Iwamura et al., (2011) investigated if elderly people prefer a conversational humanoid robot as a shopping assistant partner in supermarket shopping.^[30] Both a humanoid robot and a non-humanoid robot were used in this study. Each robot has equivalent capabilities to act as a shopping assistant, including carrying a basket for food and initiating conversations. The humanoid robot is based on Robovie II and has two arms, a head, is 1.2 meters tall, and has a camera and speaker on its head. The non-humanoid robot, or cart robot, is developed only to be function orientated. The device stands at 85 cm tall, has a camera on a pan-tilt base, and has a built-in speaker and microphone. 24 senior citizens (12F, 12M) participated in the experiment. The study was a field experiment where senior citizens shopped alongside one of the robots in a real supermarket. The results concluded that the participants

prefer a conversation humanoid robot compared to the cart robot. In addition, both the conversation and the human-like robot contributed to higher acceptance amongst the senior citizens. Qualitative data indicated that the participants had positive feelings when engaging in conversations. The humanoid robot was able to provide a sense of being "together with someone." This has positive implications in creating an assistive humanoid robot in a realistic environment, such as a supermarket, for elderly people.^[30] Two main factors need to be addressed in designing an assistive shopping robot: a) person following mechanism, b) item detection.^[29] These factors can be addressed by equipping the robot with a camera, face recognition algorithm, path finder algorithm using data of an ultrasonic or laser range finder, and item detection using a RFID or barcode reader.^[29]

Guidance and Navigator Nursing staff spends a large portion of their time guiding residents from one location to the next.^[14] One of the guidance robot's functions is to help elderly people navigate their environment by memorizing a map of the care facility.^[14] Some robots such as Pearl, a humanoid robot, are developed to assist in assisted living facilities and reminding daily routine activities such as eating, drinking, taking medicine, and using the bathroom/toilet.^[6, 14] Pearl can also detect changes in the area by using map differencing. This allows Pearl to use sensor measurements to detect any obstacle not previously recorded.^[14] This robot is 1.2m high and can give elderly patients the ability to lean on its shoulder during ambulation if needed. A study performed by Piezzo and Suzuki (2017) investigated the use of Pepper for guiding elderly individuals during walking.^[31] They tested on 8 elderly participants (3F, 5M) at two different locations, a university and an assisted care facility. Results demonstrated that all the participants preferred for Pepper to walk ahead of them. It appeared that Pepper was viewed as a guide to follow compared to an accompanying companion. The study found that elderly individuals were not afraid of Pepper upon their first interaction. All participants were also able to successfully follow the speed of Pepper. Overall, the introduction of Pepper is a good idea for a nursing home setting. The use of a robot can free up time for nursing staff and also be refreshing for the environment.^[31]

Physical activity Robots that support physical activities help older people to gain strength and force them to be active.^[19] These types of robots obtain information related to the physical activity of the elderly and relay it to caregivers or use it to adjust the robot's performance in things such as speed.^[19] An example of this type of robot is iGo, a non-humanoid walker robot, it uses the user's motion activities to adjust the walking speed by applying neural network techniques

on obtained data to have an optimal driving force.^[19] It can also identify obstacles. Robots can also be used to act as personal instructors. Shen and Wu (2016) conducted a study on 41 elderly people (25F, 16M).^[16] Comparisons in guided physical exercise were assessed between a human instructor and NAO, a humanoid robot. They identified that elderly patients strongly prefer robot instructed physical therapy over a human instructor. The robot was also shown to have similar information delivery effectiveness compared to that of the human instructor. In addition, the majority of participants liked the robotic instructor more than the human. The results show that the NAO instructor can be suitable for delivering physical activity instructors for elderly people. The robot could motivate the participants better than a human instructor, while having the same effect on information delivery.^[16] This may reduce the workload for elderly care services. Similar to NAO, Pepper can be utilized for encouraging people to exercise and partake in physical activities. It also has the capability to generate words of encouragement to motivate and entertain the elderly person.^[14]

Smart House Keeping older people independent demands a physical environment equipped with modern technologies such as smart homes and assistive robots.^[32] Sensors that are utilized in designing a smart home allows users to have control of the environment and can access different services such as security and online healthcare.^[32] Along with the smart home, assistive robots can provide comfort, emergency, and supporting services for the elderly, especially if they have mobility problems and are living alone by themselves.^[32] These robots can be accommodated in the smart house to respond to the elderly needs. They communicate with the user and elderly transferring the health status, act as a companion helping with social interaction, and serve the user by delivering meds, food, water, objects, and reminding the user of daily tasks.^[32] In one study,^[9] NAO was designed to monitor the environment and provide information about outdoor and indoor environmental situations involving the elderly with recreational activities such as playing music and handling phone calls from caregivers, asking the person to measure their blood oxygen level, and if necessary, encouraging the person to do physical exercise, locating the person's position and providing warning in emergency cases. NAO has been recently targeted to turn into an ideal low-cost tool for elderly care. RIA, an extension of NAO, improves at-home safety for independent living elderly people.^[33] The first enhancement of RIA includes a smoke detector. It will have the capability to plan alternative paths to coordinate a safe location in case of an emergency. Another feature is to detect internal body temperature. If the temperature of the patient is irregular, then the robot will alert them and the

potential agents responsible for the change.^[33] The robot can further contribute to preventative health measures like monitoring patient blood glucose and blood pressure.^[33] Another robot that was used for this purpose is the GIRAFFPLUS, a telecare system. It was created to collect an elderly person's daily behavior and physiological measurements from dispersed sensors in their living environment. The system can then organize the information and provide customizable visualization and monitoring services for both the elderly individual at home and secondary use, such as family members or other healthcare professionals.^[34] Robin, another telepresence robot, can utilize these functions to provide a safer living environment for older individuals. From a study conducted by Cortellessa et al., (2018), Robin was evaluated in terms of its cognitive workload, effective response to technology, perceived usefulness, and emotional reaction.^[34] 25 participants (12F, 13M) were included in the experiment. The participants first familiarize themselves with the multimodal interaction. Afterward, each participant was asked to perform a set of tasks utilizing the system. The overall attitude towards Robin and its services was met with positivity. There were no reports of frustration, stress, or annoyance. In addition, the robotic platform has been considered usable in its interaction modalities, usefulness, and interface.^[34] Robin was shown to effectively provide multimodal interaction to elderly people. The robot can establish virtual health-related visits to caregivers or take a proactive stance to provide daily reminders for older individuals living alone. The results suggest Robin as an effective enabling technology for telehealth service. ASCC is another telepresence robot that was designed as a home service robot. This robot, with a height of 1.5m, has several sensors such as a laser rangefinder, vision and auditory systems, a minicomputer, and batteries.^[32] Robots are not able to decide by themselves meaning that to provide the right service at the right time, especially in emergency cases, robots need to be connected to a central server and transfer the information to a caregiver requesting help.^[32]

2.1.2 Robots' Applications for Caregivers

Feeding Assistance Elderly individuals with Parkinson's disease, dementia, or another disability can find difficulty feeding themselves without assistance from another person. Feeding someone can be time-consuming and difficult for caregivers. Current non-humanoid robots have been developed to aid in the feeding process. Some of these robots include Handy1, Winsford feeder, Neater Eater, My Spoon, Meal Buddy, and Mealtime Partner Dining System. Most of these feeding systems utilize a spoon to scoop the food for the person. These robots have helped disabled and older individuals enjoy their food independently during feeding

time.^[7] MOVAID is another machine-type robot with the capability of heating/delivering food, cleaning the kitchen bench, performing daily activities, and can change bedding as well.^[7] Song and Kim (2012), have taken the idea of these feeding robots and extended their capabilities.^[35] Their team introduced a newly designed self-feeding robot that is suitable for Korean food. The experiment tested primarily on individuals who have physical disabilities and senior citizens with difficulties moving their upper limbs. The robot consists of two unique arms: a spoon arm and a grab arm. Together, the arms can pick up/release the food and transfer the food to the person's mouth. The feeding process is controlled by the user. Both buttons and joysticks were incorporated as controls for feeding. The results showed that the majority of participants reported that the self-feeding system operated well.^[35] Users were impressed that they could choose the food they wanted to eat at will. There is also a single-arm configuration that allows caregivers to load the food onto the robot for feeding. The user can then freely choose the timing of when they want to take each bite. This robotic design can allow both disabled and elderly individuals to control the robot themselves, as well as take away some of the caregiver burdens to manually feed the person.

Laundry/garbage handling and water delivery The SMOOTH project was established to design a mobile welfare robot of limited complexity. The project's overall goal was to mitigate the challenges presented by elderly people, while aligning the expectations of the user with the capabilities of the robot.^[36] The creation of the SMOOTH robot was influenced by the design of previously well-established robots including Care-O-Bot 4 (managing laundry and garbage), Pepper (guiding the elderly from one place to another), and MiR100 (for water delivery and encouraging the elderly to drink). SMOOTH is equipped with wheels, a handle to move it easily, and a basket for carrying either a person's laundry or drink.^[4] The external factors of affordability, modularity, simplicity, and acceptability were considered in the robot's development.^[36] For the robot's acceptability, only minimal anthropomorphic features and facial features were included to facilitate interaction. SMOOTH is also able to calculate an optimal path around obstacles in the environment to contribute to the safety of the elderly person. The robot currently can transport garbage, perform laundry pick-up, and provide some guidance.

Lifting assistance Transferring patients from one location to another can be hindered by heavyweight restrictions. The caregiver may have limitations in helping lift or turn their elderly patients in bed. Healthcare workers also often need ample assistance with patient-transfer tasks between a bed and a wheelchair. Mukai et al., (2010) explore the possibility

of developing a robotic prototype that can lift a human in its arms.^[37] A Robot for Interactive Body Assistance (RIBA) was created to safely handle an elderly person. The patient-transfer ability was evaluated by testing 10 adults (9F, 1M). The ability to lift a person from both a bed and wheelchair was tested. Conversely, placing a person back in bed and the wheelchair can be managed by applying the reverse motion. The caregiver has an assistive role alongside RIBA. The caregiver is required to make fine adjustments to the robot to line up properly with the elderly person. In addition, the caregiver also must use one arm to assist the person's head during the lifting or placement process. It was observed that lifting was stable and there was no danger of dropping the person. RIBA succeeded in its function in transferring a human from a bed or wheelchair and back using its human-like arms.^[37] It was noted that RIBA was the first robot to perform this action for people without a reclining function. Furthermore, the robot can lift people with a weight of up to 63 kg. The guidance method of RIBA also allows the caregiver to be near the person, which may be less stressful for elderly people.

Medication delivery Statics show that keeping older adults in their own homes is more cost-effective than keeping them in elder care facilities.^[38] The problem with keeping them at home is medication management. Poor adherence to taking prescribed medications on time is a concern for the elderly population. Drug non-compliance may pose serious threats for older people. Three common forms of drug treatment non-compliance come from overuse and abuse, forgetting, and alteration of schedule and doses.^[39] Addressing one or more of these three issues can help promote independent living and quality of life for older people. Electronic devices have already been developed to remind and monitor medication administration. Currently, medication monitoring has expanded into robotics. Programming the robot allows caregivers to deliver the right medication to the right person at the right time.^[7] Medicine delivery by a robot can also motivate the person to take the medicine.^[7] One of these robots includes the Healthbot robot. Tiwari et al., (2011) tested the Healthbot on 10 participants (5F, 5M) ranging from the ages of 69 to 94.^[40] All of the participants were arranged to meet the robot medication assistant in the morning to remind each person of their medication. The user was also asked by the Healthbot to read the bottle label and confirm the correct medication. This can provide a small cognitive exercise for the elderly person, instead of simply receiving the medication. Each participant also could deny the medication. However, the Healthbot does attempt to elicit the answer for the medication refusal to determine if the patient is not feeling well. This information can then be reported to their caregiver or to the prescriber to modify the medication

to the patient's personal preference. These features were developed to promote patient safety. Overall, older adults completed the tasks successfully, felt confident utilizing the new system, and found it to be easy and simple.^[40] PR2, is a humanoid robot that was used by Parkash et al., (2013) for medication management.^[38] Their goal was to design an efficient med-manager robot to consider people's preferences and concerns.^[38] Cognitive decline is a major problem that older people have that makes it hard for them to remember what medicine needs to be taken. Robots' persistence in delivering the medicine is one of the concerns that needs to be considered.^[38] Disabled people also have mobility problems so the med-manager robot should have the ability to move around and deliver the medicine and water to the person.^[38] The robot appearance, designing algorithms, the way the robot delivers the medicine using its hands or gear, transferring speed, and robot distance with the person are all factors to be considered when designing a successful med-manager robot.^[38]

Virtual presence Caregivers are not always able to be physically present with an elderly patient. With the introduction of technology in healthcare facilities, telepresence can create a physical presence in a virtual space. Telepresence robots allow the user to interact with a patient from a remote area through robot mobility, live audio, and video feed. Koceski and Koceska (2016) developed an assistive telepresence robot to investigate its use and acceptance amongst the elderly.^[41] The objective was to effectively communicate and interact with the elderly to support caregivers in everyday care. The robot consists of a mobile base and robotic body that includes a linear actuator, robot manipulator, and robot head represented by a tablet. The participants were placed into two groups. The first group consisted of 30 elderly participants (13F, 17M) ranging from the ages of 65 to 78, and the second group consisted of 5 professional caregivers. The study included four different experiments. The first two experiments called for the elderly participants and the caregivers to maneuver the telepresence robot to test its functionality. The elderly participants also utilized the video conference application, while the caregivers utilized the electrocardiograph function to test the elderly participants. The third experiment was conducted to test the robot manipulator. The elderly participants were asked to fetch and carry small objects with the robot. The final experiment tested the reminder functionality of the robot. The elderly were able to utilize the robot's capability to remind them about taking medication or calendar events and appointments. The results had shown that the telepresence robot made a positive impact on both the elderly participants and the caregivers. The robot allowed the elderly to perform activities of daily living with ease while re-

ducing caregiver burden.^[41] In addition, robotic acceptance was high amongst the participants. Questionnaires elicited positive feedback about the robot system. Many participants also reported being willing to use a developed telepresence system in both a social and medical setting.^[41]

3. DISCUSSION

The utilization of humanoid and non-humanoid/animal-like robots can be beneficial in its real-world applications. As previously discussed, robotics can be integrated into society through several approaches. This review of literature identifies the division between robotic applications for the elderly, a smart house, and caregivers. Methods for assisting the elderly and their caregivers focus on both the robot and human interactions, as well as their subsequent acceptance of the robot into daily life.

Identifying a mechanism to help elderly people in an assisted living facility or another healthcare setting can alleviate the stress placed upon healthcare workers. Healthcare facilities can present with a shortage of workers. This can create difficulties providing individual care for patients. As a result, patients or residents can experience a reduced quality of life. A potential solution in helping the healthcare worker shortage is to integrate robots and innovative sensor solutions for monitoring and recording vital signals. Robots can act in coordination with current healthcare staff to accomplish daily living activities for elderly patients. One method of robotic assistance is patient guidance and navigation. Pearl is a mobile robot that can analyze and memorize its environment to properly direct elderly patients to specific locations.^[14] Pepper also has been used as a guidance robot due to its appropriate height and speed.^[31] Some limitations may arise due to the speed of the guidance robots. It is important for the robot to not travel at a fast pace to prevent elderly falls and also adjust the speed with the user walking speed. To account for balance support issues, some robots have cameras to monitor gait parameters of elderly patients.^[31] The robots can then adjust the speed at which it needs to travel to match an appropriate walking speed.

Another approach for helping elderly people is promoting physical activity. Muscle wasting and reduced range of motion can occur for those with limited mobility or long-periods of inactivity. NAO has been shown to guide physical exercise sessions for elderly patients. Humanoid robots, including NAO and Pepper, have been successful in encouraging people to perform daily exercises. To further add, elderly people have shown to have a preference for robot-guided physical therapy sessions over the live-human counterpart.^[16] It has been suggested, however, that there may be variability in instruction styles between a robot and a human instructor.^[16]

It has been noted in a study conducted by Dautenhahn (1999) that predictability and lack of interaction can make a foreign agent appear less frightening for inexperienced users.^[42] This may account for why elderly participants prefer robot-guided physical therapy.

Both Pearl and NAO possess an extensive library for elderly assistance. Their use in supporting those with mild cognitive impairment has been a large area of interest for many researchers. Preventative healthcare measures against cognitive decline are an expanding area of medical research. Pharmaceutical and non-pharmaceutical interventions to slow the progression of debilitating cognitive illnesses, such as Dementia and Alzheimer's disease, are constantly being developed. The introduction of robotics has significantly impacted the non-pharmaceutical management of mild cognitive impairment and dementia. A specific capability that allows robots to assist those with mild cognitive impairment includes providing daily reminders, like taking essential medications, and when to perform these tasks.^[14] In addition, when memory training is conducted by a robot, elderly people with mild cognitive impairment experience more attention and less depressive symptoms than a common memory training protocol.^[23] People suffering from moderate to severe forms of dementia may have difficulties successfully responding to robotic therapy. Patients with later stages of dementia were found to have increased delusions and irritability working with humanoid robots.^[43] Furthermore, similar patients working with animal-shaped robots experienced a decrease in quality of life, increased hallucinations and irritability, and increased disinhibition.^[43] The use of robotics for people living with cognitive impairment must then be assessed on a case-by-case basis to determine its potential effectiveness.

Robot acceptance is important for elderly people to establish trust if they must interact together under the same household. Pet-like robots, also known as companion robots, serve as a friend for an independent-living elderly individual. Their main purpose is to serve as a therapeutic agent for people. A well-known animal robot used in various research studies is Paro. Its seal-like appearance has been shown to provide a sense of pleasure and relaxation for older individuals. Additional aspects include reducing levels of negative affect, stress levels, and mood improvement.^[27]

Another application of elderly robotic assistance mentioned is grocery shopping. Grocery shopping assistance applies to elderly individuals who have the ability to shop independently. Robots such as CompaRob or Robovie have enabled the elderly to boost their physical capability and quality of life. These robots are classified based on their function as

either a shopping cart or store shopping assistant. Not only can they potentially help in the shopping process, but these robots can engage in conversation with the elderly in the supermarket.^[30] Current development is underway to create item detection. This will allow the robot to reach for items to add to its shopping cart.^[29]

Humanoid robots are now being incorporated directly into an elderly person's home. A smart house, or home automation, can monitor and control home attributes. A smart house would have significant benefits including independent and assisted living, convenience, safety, privacy, and centralized control in hopes to enhance the quality of life for its occupants.^[44] NAO has been designed to monitor the living environment to provide essential information about the household condition. Internal conditions such as body temperature, blood glucose, and blood pressure can be closely monitored through robotics.^[33] The robot can then transmit information about any drastic changes in a person's health to their provider.^[34] Additional features of robots in smart houses is their recognition of abnormal housing temperature, humidity, gas, and fire detection.^[6,33] Ultimately, robots have been demonstrated to improve at-home safety for elderly people living independently.^[33]

It can be said that robots have impacted the elderly population in several ways. The underlying implications of robotic assistance have also given substantial burden relief for caregivers. Being a caregiver is rewarding. Helping a loved one is something that many people wish to provide. However, a caregiver may be too focused on their loved one and may neglect their well-being. One of the strategies recommended by the Mayo Clinic to reduce caregiver stress is to focus on what you can provide and seek alternative solutions.^[45] Fortunately, the emerging field of robotics in healthcare has provided one such alternative solution. Various humanoid and non-humanoid robots have been developed to tackle daily tasks that are required to care for an elderly loved one.

One of the most routine tasks in helping elderly people is delivering medication and water. Drug-noncompliance can have serious negative effects on the overall health of an individual. One of the most common reasons for drug-noncompliance for older people is simply forgetting.^[39] It can also be hard for caregivers to manage the timing of the medications if there are many of them. Medicine delivery robots are thus created to remind and monitor medication administration.^[7] This allows the medication to be delivered to the right person at the correct moment. A prime example of a medication delivery robot previously discussed is the Healthbot robot. The robot can also respect patient autonomy and give the right for older people to refuse medication. Health-

bot can then report medication refusal to their caregiver or prescriber in hopes to improve drug-noncompliance.^[40] PR2, another humanoid medication robot, can manage medication for disabled people. It has the capability to move around to deliver both medication and water to the person.^[38] Current issues around robotic medication delivery are the issue regarding persistence.^[38] Some robots do not have the ability like Healthbot to not administer medication if a patient refuses. Future designs must be considered to take into account a person's perspective if they choose to deny their medication.

Another activity that may be time-consuming for healthcare workers and caregivers is feeding. Many robotic designs have already been created to tackle this dilemma. Creating a system that will allow older or disabled individuals to eat their food without human assistance can promote independence. An innovative robotic system called MOVAID has the mechanics to heat and deliver food. Further designs have taken this idea one step further and developed a system to manually feed a person. Robots with multivariable arms can be controlled by an elderly person for self-feeding.^[35] Additional features allow the user to freely control what they want to eat and the timing of each bite.^[35] Ideas of a self-feeding system can potentially alleviate a portion of the caregiver burden.

Living independently requires that the person perform essential household responsibilities. Some of these tasks may include doing the laundry or taking out the garbage. If the purpose of robotics is to promote independent living for older individuals, it is advisable to incorporate functions that can assist in these routine tasks. The Care-O-Bot 4 is a robot that provides services such as managing laundry and garbage.^[36] The robot MiR100 is a robot that is specialized to deliver objects to elderly people, such as water.^[46] If an elderly person wanted to walk around their home to do something, the SMOOTH robot can detect an optimal path for them to travel to avoid any hazardous obstacles. Together, these robotic features assist elderly people in their own homes to promote comfortability and safety.

It was mentioned that healthcare workers often find difficulty transporting heavier patients. Assistance in transferring patients between a bed and a wheelchair can be accomplished through robotic development. The robot RIBA can now lift a person from their bed and place them in a wheelchair.^[37] Conversely, the same robot can reverse its motion to place the person back into bed. The robot currently can only lift people who weigh up to 63 kg. Consequently, RIBA was developed in Japan and addressed the general weight of their patients. The differences in body weight for elderly people in

the United States can pose difficulties for the current version of RIBA. Expansion of a robot's weight capacity will need to be addressed to develop a similar patient lifting system in US healthcare.

The final application discussed for caregiver assistance in robotics is telepresence. It can be difficult for families to constantly monitor their elderly family members at a remote location. At the same time, elderly people do not often want to lose their independence and move in with their family or an assisted living center. The answer to this challenge can be immediately solved through telepresence. Telepresence robots, such as Robin of the GIRAFFPLUS project or RoboLAB10, offer families an immediate connection with their elderly loved ones through a virtual space. Studies have shown that these robots have made a positive impact on both the elderly individual and their caregiver.^[41] It was also important to note that telepresence robots were highly embraced and accepted amongst older people in their homes.^[41] Although telepresence may not have the same psychological effects as an in-person encounter, these robots allow elderly people to remain connected with their caregivers or family. This can positively contribute to their overall safety and well-being.

4. CONCLUSION

Assistive robots for the elderly are designed to help those who have problems with walking, need physical assistance by walking beside them, and help with physical exercise. Other functions may include encouraging them to follow the robot, helping to take their medicine, performing home chores, helping them to recall their memory, and improving their cognitive level by playing music, displaying videos and pictures, playing games, communicating with them to prevent them from feeling socially isolated and alone, and making video calls with family and caregivers.^[9] To have full control over the individual's health situation and maintain

their independence, it is necessary to have an IoT solution which is a combination of different sensors and technologies such as health monitoring sensors such as blood pressure, EDA/GSR, and heart rate measuring, smart home sensors such as cameras, automated door control, fall detection, pressure sensors, and robots.^[5,9]

Designing fully automated robots is one of the main challenges that researchers are faced with. Applying artificial intelligence concepts and machine learning techniques allows the robots to learn from the experiments. But the problem is that in emergency cases, services should be provided immediately. Also, assistive robots should be affordable to buy, trustable, and acceptable. Available humanoid robots are too expensive and they are not fully automated meaning an operator needs to control the robot via a server or update its software. To transfer the user health data via a server the privacy of the data and security of the network should be considered. Also, older people may not feel comfortable with using the technology and the robot all the time, or in the long-term, they may not show any response to the received signals from the robots. Thus, motivating the elderly to stay in touch with the robot is another issue that needs to be focused on in future research. As the elderly show different responses to different types of robots-humanoid and animoid-based with their health condition, it may be useful to have a combination of both types of robots.

AUTHORS CONTRIBUTIONS

This paper was proposed by Dr. Arshia Khan and written mostly by Richard Sather and Mahsa Soufineyestani. Dr. Khan met with the students each week to review the paper and suggest changes and make edits. She made revisions. Nabihah Intiaz worked on the reference formatting and reviewed the grammar.

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