

Use of Humanoid Robot in Dementia Care: A Literature Review

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ABSTRACT

Dementia is a prevalent age-related disease that affects an individual's quality of life. Cognitive decline is the most common symptom of dementia that consequently causes problems with memory, language, and apathy, communication, thinking ability, difficulty in problem-solving and doing their daily living activities independently. In recent years, researchers have tried to improve the quality of life of people living with dementia by utilizing new technologies such as robots. This study aims to investigate specifically the application of humanoid robots in refuting the risk of dementia by focusing on three approaches: 1) cognitive-communication improvement, 2) psychomotor therapy, and 3) music therapy. The results indicate that having humanoid robots as companions may serve as an effective therapy that helps people living with dementia (PLwD) with their cognitive function, motor skills, language, and communication skill. It also may decrease psychiatric symptoms by involving PLwD which will lead to improvement in their quality of life. The humanoid robots can also help reduce cognitive decline by helping PLwD perform exercises.

Keywords: Dementia; Humanoid robot therapy; Elderly; Caregiver

INTRODUCTION

Approximately 50 million people suffer from dementia worldwide. The World Health Organization predicts that this number will grow to 82 million in 2030 and 152 million in 2050 [1]. People with dementia (PLwD) suffer from loss of memory, language, problem-solving and other thinking abilities that interfere with daily life [2]. Besides cognitive decline, dementia also contributes to psychological changes including personality changes, depression, agitation, and hallucinations [3]. A current cure for this debilitating disease has not yet been discovered. As a result, efforts have been diverted to improve a person's quality of life. The treatment goal for dementia is to keep the person safely at home performing daily living activities for as long as possible and provide support and guidance for caregivers [4]. Pharmacological and nonpharmacological treatments can help stabilize the PLwD condition and delay the progression of symptoms. Non-Pharmacological treatments may improve autonomy and quality of life of dementia patients by concentrating on strengthening activities mentally, physically, and emotionally [5]. Robot therapy is one of the non-pharmacological therapy solutions for PLwD that can reduce

agitation, decrease loneliness, improve mood, and improve social interaction [6].

LITERATURE REVIEW

Studies promoting brain activity in dementia patients have shown to slow the progression of the disease. The methods to promote brain stimulation vary in its approach. One method for stimulating brain activity has come with promoting social interaction. Lack of communication due to language impairment is one of the initial signs of cognitive decline [7]. One study [8], examined the late-life engagement in social and leisure activities for people with dementia. They noticed that both social interaction and intellectual stimulation may be ideal in preserving mental functioning in elderly. Another study [9], investigated social engagement before and after dementia diagnosis in the English Longitudinal Study of Ageing. The team discovered that social engagement significantly reduced dementia risk. The conclusion was to promote social interaction in older adults. One longitudinal study [10], tracked differences between healthy participants that received consistently high social engagement with those with consistently low social

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engagement. The study took place in China, and it centers on changes in social engagement and its subsequent association with dementia risk amongst older individuals. Participants with consistently high social engagement had a reduced risk of dementia than those with less engagement. In addition, increasing social engagement was associated with a lower risk of dementia.

Another approach to slow down dementia progression is encouraging daily exercise [11], dance [12], and walking accompanying [13]. In a review conducted by Kirk-Sanchez and McGough, looked at how current forms of physical exercise can target modifiable risk factors, such as age-related cognitive decline and disease-related cognitive impairment in older individuals [11]. Exercise programs that are structured, individualized, higher intensity, and longer in duration show positive results in maintaining cognitive performance in older adults. From this review, exercise may serve a purpose to protect against cognitive changes related to neurodegenerative diseases such as Alzheimer's disease. Exercise is not only essential in reducing the risk of dementia but also for establishing positive mental health. The relationship between exercise and mental health has been extensively studied. A study by Deslandes, et al., reviewed how physical exercise might represent an adjunctive treatment for neuropsychiatric disorders and cognitive impairment [14]. The review found that moderately intense exercise reduces the harmful effects of daily stressors. Although exercise may be perceived as a stressor itself, evidence suggests that exercise ensures successful brain functioning to promote positive mental health.

A final approach in delaying or preventing dementia's symptoms are through music. Listening to music can have multiple effects on the human mind and body. Music is also a non-medical treatment that can help improve the quality of life for PLwD. Listening to music can help social engagement, support physical activity, elicit a positive mood, evoke emotions, and create a common interest between PLwD and their caregiver. A review by Baird and Samson discussed how PLwD particularly enjoys music [15]. Their response to music is potentially preserved in the late stages of dementia when verbal communication is ceased. The review of various music related studies and dementia shows that listening to music can provide an important link to the person's past. Music can also act as a method for nonverbal communication with the caregivers. Thus, listening to music can be an effective stimulus for PLwD and potential strategy to relieve stress on the caregiver. The expansion into music therapy has opened new areas for interacting with PLwD. In a systematic review and meta-analysis by Zhang, et al., 34 studies were reviewed to analyze the efficacy of music therapy in elderly living with dementia and to understand whether music therapy can be used as a first-line non-pharmacological treatment [16]. Results showed that music therapy could be effective when PLwD received interactive therapy. The evidence supported music therapy as a form of treatment for cognitive function, depression, and quality of life [16].

Performing these various activities for PLwD may be difficult depending on the mental state and physical capabilities of the

caregivers. A systematic review conducted by Cuijpers reported that the prevalence and incidence of depressive disorders are increased in caregivers of dementia patients [17]. Likewise, mild levels of depression can add to the functional impairment of dementia patients and the severity of neurological impairments increases with increased depression [18]. It is then important to identify ways to improve the quality of life for both dementia patients and their caregivers. Prescribing medication that slows down dementia symptoms and using non-pharmacological approaches are the only available treatments that can improve the patients' situation [5]. Significant levels of stress can inflict caregivers as the burden increases with late stages of dementia. A review of the burden of dementia patients' caregiver conducted by Eters, et al., identified current factors influencing dementia-related caregiver burden [19]. The conclusion demonstrated that caregiver burden manifests itself in multiple ways: gender, relationship with patient, culture, and personal characteristics. The approach to solving these barriers is to develop multicomponent interventions to decrease overall burden and promote quality of life. Thus, the area of humanoid robotic research is at the forefront of solutions for managing long-term dementia patient care. Humanoid robotics come in various forms; the American Society of Mechanical Engineers list 10 humanoid robots of 2020: robotic avatar, robotic ambassador, delivery robot, research humanoid, digital humanoids, robotic bartender and actor, robonauts, educational robots, and collaborative humanoids [20]. The current clinical applications of humanoid robots are limited but continue to show growth in daily life, especially in the field of healthcare. Some of these areas include pediatric healthcare, dentistry, senior living, special education, and physical therapy. The purpose of this review is to focus on humanoid robots and how they can be used to help people living with dementia and their caregivers. In the following section, the current types of humanoid robots will be listed. It is important to note that each humanoid robot is limited for what they can do. Each robot is designed to accomplish a specific task. To add, the robots that we will discuss are self-sufficient and are semi-autonomous. Each humanoid robot is further assigned into three different categories: none-mobile, mobile, and projected. We will then discuss how these humanoid robots can provide non-pharmaceutical treatments for dementia patients in the perspective of 1) cognitive-communication improvement, 2) psychomotor therapy, and 3) music therapy. Finally, we will discuss the results and conclusions of the studies.

Application of humanoid robots in dementia care

Humanoid or conversational robots have an appearance similar to the human and are categorized into three distinct categories: mobile, none-mobile, and projected. These robots usually have a head similar to a human face, a neck which allows multidirectional movement of the head, a torso which is equipped with a screen or tablet for communicating with the user, two arms, and may have legs/wheelbase leg (Figure 1). A humanoid robot usually is equipped with sensors allowing the robot to identify an obstacle, recognize humans and identify their emotions, may follow or move toward an object based on the mobility of the robot, communicate with individuals

through its speaker using natural language techniques [21]. They can work in two modes, remotely controlled or autonomous and are programmed to do specific activity [21].

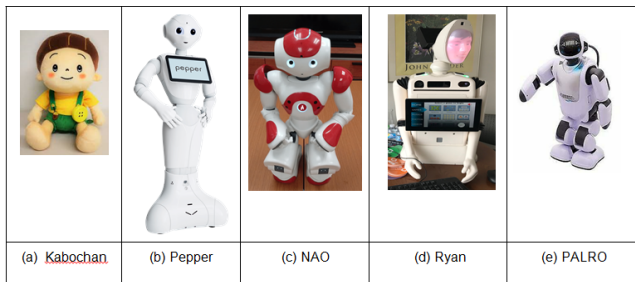


Figure 1: Different types of humanoid robots.

Humanoid robots can be utilized for different purposes including: improving communication skills, assisting the individuals with their daily life, engaging and involving the individuals with various kinds of activities such as exercising, listening to music or entertaining them. One of the main problems with robot therapy is technology acceptance between PLwD. Chen, et al., and investigated acceptance of a humanoid social robot (Kabochan) between people living with dementia [22]. They recruited 103 participants aged 67-108 diagnosed with moderate or severe dementia from seven long-term facilities in Hong-kong. Participants were divided into two groups; an engagement group or a control group. Fifty-two PLwDs were in the robot engagement group interact with a humanoid social robot called kabochan and 51 PLwDs were in the control group receiving normal care. Research assistants questioned Pwds about their attitude toward Kabochan, usefulness, ease of use, self-efficacy, facilitating conditions, and anxiety of using kabochan during week 1,8,16,24 and 32. Also to see individuals' engagement response, their engagement behavior factors such as talking with, cuddling, carrying and feeding the robot, and so on was recorded. To measure engagement level of PLwDs with the robot, videos were captured during the time they were interacted with the robot. Statistical analysis indicated that being engaged in the robot could gradually increase the robot's ease of use but no significant changes were seen in individuals' attitude toward robot acceptance.

Cognitive-communication improvement

Mild Cognitive Impairment (MCI) is the stage between the normal expected cognitive decline from aging and a more severe form of cognitive impairment as dementia. The initial presentation of MCI may include forgetting things more often, forgetting important events, losing thought mid-conversation, feeling overwhelmed by decision making, or difficulty finding yourself around a familiar environment [23]. The culmination of these symptoms can contribute to secondary factors, such as depression and anxiety. Addressing the concerns regarding both dementia and emotional disturbances is important for creating a proper medicinal and non-medicinal treatment plan. Together, this will affect the quality of life (QoL) for the dementia patient that involves many cognitive abilities such as attention, memory, language, and abstract thinking [24]. Based on the definition of the World Health Organization, QoL is the individual's perception of their position in life in the context of culture and

value system in which they live, and in relationship to their goals, expectations, and standards [24]. PLwD's quality of life declines with early stages of cognitive disorder and it is more common in people with MCI [24]. Different methods are examined by the researchers to prevent cognitive decline and boost quality of life. Currently, robotics has integrated communication with PLwD to enhance cognition levels [25], as well as to reduce caregiver stress [22]. Utilizing speech, facial expressions, and communication gesture features of a social robot help clinicians and caregivers to enhance PLwDs' social interaction and support them in their activities of daily living [26].

One of the major issues of PLwD is the problem with language, which is directly related to cognitive decline. Decline in language has a negative impact on communication skills of the patients with their caregivers [7]. To solve this issue, researchers tried to improve PLwD' communication skills by interacting with a humanoid robot. Utilizing robots in therapy sessions allow individuals to express themselves and improve their language skills. For instance in one study [7], humanoid robots utilized to interact with patients by having conversations and helping them to improve their language ability and communication skills [7]. Pou-Prom, et al., evaluated cognitive performance of patients with mild, moderate, and severe dementia [7]. They designed an experiment which displayed several pictures to patients and asked them to describe the pictures or answer questions that were asked by a human, a remotely controlled or an autonomous robot called Ludwig. The results indicated that patients could communicate well with the robot. Also, they had longer conversations with humans rather than the robot. In addition, it was observed that sometimes patients could not understand what the robot was trying to say or ask so they could not provide a correct response to Ludwig or they became confused. It was also noticed that patients had more problems with an autonomous robot. In this case the robot could not remember the previous conversation with the patient and conversation could not last for a longer period [7]. In another study [25], researchers concluded that using humanoid robots as part of a therapy treatment for PLwDS can boost their psychiatric symptoms, leading to improvements in their quality of life. Abdollahi, et al., used a companionbot called Ryan to test how interaction with a customized robot can change the quality of life of patients with dementia, and/or depression [25]. Ryan communicated with individuals through spoken dialog, recognized their emotions by reading their facial expression, and entertained them by playing their favorite songs or movies related to their favorite topics, designing cognitive games, and telling stories by showing them pictures from them or their relatives. Results of this pilot study on six patients indicated that patients enjoyed their accompaniment with Ryan; those who were depressed felt happier, patients laughed more. Additionally, enhancement in cognition level and improvement in mood was reported by the caregivers [25]. In a study by Chen et al., they utilized the Kabochan robot to understand whether interacting with the robot can affect patients' psychiatric symptoms or decrease caregiver distress and work-load [22]. They did not observe any significant differences between the control and intervention group. Although removing the robot from the

intervention made patients' psychiatric symptoms more severe, it did not have any impacts on their quality of life, depression, or cognitive level. Also a short-term decrease in caregivers' distress level was noticed during the weeks 9 and 16 of intervention. To have a clear conclusion about the impact of Kobachan on PLwD, it was suggested to personalized robot therapy for patients based on their health situation [22]. In another study by Inoue, et al., a humanoid robot called PALRO was used to interact with PLwD [27]. This robot can connect to the internet to collect various information, such as news, fortune-telling, weather, and forecast. The purpose of the study was to allow PALRO to identify which activity would be most effective to alleviate the conditions of PLwD. The study included Dementia Care Mapping (DCM), which analyzed the quality of care through the eyes of a dementia patient [27]. Twenty-five participants with varying stages of dementia were involved in the study. The DCM mappers (observers) took note of Behavior Category Codes (BCC). Results showed that people with severe dementia tended to note objects, verbal and non-verbal interactions with others. Seniors with mild dementia tended to prioritize the use of intellectual activities and engage in leisure, fun, and recreation. The results showed that PALRO encouraged PLwD in their communication, activity expressions, intellectual activities, and fun. PALRO was found to work better for people with mild dementia compared to severe dementia. Overall, this humanoid robot can be combined with medicinal treatment to help patients with different activities [27].

Psychomotor therapy (exercise)

Psychomotor activity is a motor or physical activity that is secondary to a cognitive component. This type of activity can be used as a non-medicinal treatment for dementia patients.

Psychomotor therapy can be performed as dance [28] or exercise therapy that sometimes is combined with music therapy [29]. Dance therapy which is one of the effective therapy especially for PLwD with language problems [28]. It motivates individuals to express themselves and their thoughts non-verbally and improve their communication skills [28]. Dance therapy can be used to decrease irritability or depression, increase self-esteem, important factors for positive mood in dementia [30]. Exercise therapy consists of several steps such as warm-up exercise gently movement of body parts and gestural movement [28]. The introduction of robots for exercise therapy can decrease the cost of care and the work burden of caregivers [12,13], address the shortage of caregivers [12], and enhance patients' motivation and apathy [13]. Humanoid robots can help the therapist assistants by trying to involve the patients with the physical activities [29].

Physical activity and dementia is currently an area of continuing research. Several researchers conducted a study based on a meta-analysis and systematic review between physical activity and the risk of cognitive decline [30]. The overall results suggest that physical activity is a beneficial and important modifiable risk factor for reducing the risk of Alzheimer's disease, all-cause dementia, and cognitive decline. Further results showed that moderate physical activity may be enough for reducing the risk of all-cause dementia [30]. Another study by Rouaix, et al.,

compared two therapist sessions on PLwD; one conducted by a therapist, another conducted by both therapist and a robot called NAO [29]. Patients conducted by the therapist, robot, or both to do physical and breathing exercises, and talk about their body in order to increase body awareness and measure their verbal skills [29]. NAO was programmed to engage the participants by talking with them and encouraging them to try the experiment. Qualitative and quantitative analysis of psychosocial and surveys showed participants had more emotional responses during interacting with both therapist and robot. But, there was no difference between engagement level of participants between sessions conducted by therapist or therapist and robot. It also was concluded that having a robot companion increased well-being and satisfaction of individuals [29].

Music therapy

Music has been associated as a non-medicinal treatment for many debilitating diseases especially for PLwD that have lost their ability to speak [30]. Music treatment approach in which music is played and conducted by a music therapist called music therapy otherwise if music played by caregivers called music intervention [31]. Music therapy is often used in the clinical setting for dementia patients.

Several studies have shown that PLwD enjoys listening to music. The response to music remains intact even in moments when verbal communication is not possible. A meta-analysis and systematic review conducted by Moreno-Morales, et al., analyzed eight studies that focused on music therapy as a treatment for dementia [32]. The analysis demonstrated that music intervention with music improves cognitive function for those living with dementia. In addition, the QoL and long-term depression improved after the music therapy sessions [32]. Recently, researchers tried to replace humanoid robots to conduct the music treatment session. For example Kok, et al., created a study using Pepper to play music for patients with dementia [33]. The purpose of the investigation was to allow users to relive their memories and give them a sense of hope, familiarity, and security. The robot was programmed to play music that most vividly interacted with a specific patient between their age of 15-25. The study focused on certain questions and measures that provided both quantitative and qualitative results. The quantitative results addressed whether the PLwD started talking about past experiences after listening to the music and the level of comfort for the PLwD according to the caregiver. From the seven participants that were tested, 71.4% started talking about their past after listening to the music. The results show that the majority of PLwD tested chose to link a conversation to a memory that they had about a particular song. In terms of comfort level, 42.9% experienced a higher comfort level than before entering the testing room, 42.9% remained the same, and 14.3% level of comfort decreased. The decrease in comfort was attributed to negative emotions to a specific song that was played. Qualitative results were also gathered on each participant. Overall, the majority of participants really enjoyed the music Pepper played. Many were surprised how the robot recognized their favorite songs growing up. All participants wished to interact with Pepper after

experimentation. Robot acceptance was very high amongst PLwD from this standpoint. Signs of liveliness, smiles, and tears indicated increased happiness. Furthermore, the detailed stories about the songs indicated that music can evoke memories in people with dementia [33] (Table 1).

| Paper | Robot | Experiment | Participants | Results |
|-------|---------------------------------------|---|--|--|
| [7] | Ludwig (Milo R25 robot from Robokind) | Describing pictures | No. 19 (M: 3, F:16) Age: 67-94 MMSE score: 2-19 Nursing home Mild, moderate, severe | Longer conversion with human |
| [29] | NAO (Softbank robotics) | Relaxation | No. 9 (M:2, F:7) Age: 68-95 MMSE score: 12-22 Geriatric Hospital Control group (patient-therapist) Experiment group (Patient robot) | Increase in well-being and satisfaction |
| [25] | Ryan (DreamFace Technologies, LLC) | Music therapy, Reminiscence, Cognitive game | No. 6 Moderate dementia and depression Senior living facility 4-6 weeks 24/7 access to the robot | Improve in quality of life, Happier and more laugh |
| [22] | Kobachan | Robot engagement | No. 103 (52: engagement and 51: symptoms) | Improve in psychiatric symptoms |

| | | | | | |
|------|----------------------------|---|--|---|--|
| | | | control group) | | |
| | | | Aged: 67-108 | | |
| | | | Seven nursing facilities | | |
| | | | 32 weeks | | |
| [5] | NAO (Softbank robotics) | Physiotherapy, music, and logic-language sessions | | A research center | Slight or mild improvement in neuropsychiatric |
| [33] | Pepper (Softbank robotics) | Social Therapy Music Therapy | No. 7 | Laurens Liduina home for people with dementia | High robot acceptance for PLwD Increased happiness Ease of caregiver usage |
| [27] | PALRO (Fujisoft Co.Ltd.) | Identification Robot | No. 25 (M: 6, F:19) Age: 86.6 average Nursing home | | Encouraged communication, activity expressions, intellectual activities, and fun in PLwD |

Table 1: Music therapy experimental results.

DISCUSSION AND CONCLUSION

In this study we considered the role of humanoid robots in cognitive-communication improvement, psychomotor therapy, and music therapy for PLwD. The results show the efficacy of utilizing humanoid robots as a non-pharmaceutical treatment for PLwD. Mild cognitive impairment is linked to the normal aging process and more severe forms, such as dementia or Alzheimer’s disease. A notable impairment that comes with cognitive decline is language. The use of humanoid robots was incorporated in research to slow the progressive loss of language. Robots have the capability to interact and communicate with humans. Creating a conversation can help preserve their language ability and communication skills. In some instances, individuals were shown to prefer robot interactions over a human. Complications arose when the robot was not able to understand what the patient was saying or if it could not recall previous conversations. Besides language, humanoid robots are multifaceted. The companionbot Ryan has the ability to engage in conversation, recognize their emotions through facial expression, entertain them by playing their favorite songs or

movie, design cognitive games, and show them pictures of their family or past. Together, this has helped alleviate secondary symptoms of depression, as well as reduce care-giver stress to continuously entertain and monitor their loved one. Humanoid robots are also learning to adapt to PLwD. PALRO can gather information on what specific activities that interest a person. This develops an approach to identify what particular behaviors or interests a PLwD will display depending on the severity of their cognitive impairment. Another method that was discussed to prevent progressive cognitive decline is physical activity. Psychomotor activity can be used as a non-pharmacological treatment for dementia patients. Psychomotor therapy guided by a therapist and humanoid robot has been shown as an invaluable resource. NAO can be utilized to actively engage with a participant. The robot acts as a companion for PLwD during exercise. As a result, an emotional bond is developed through working with the robot. Well-being and satisfaction of the dementia patient increased in addition to exercising. Finally, listening to music has therapeutic effects for those living with dementia. PLwD often find comfort listening to music that they are familiar with. Importantly, it can help any depression that may be comorbid with dementia. The goal for music therapy is to relive past memories that are closely linked with a particular person. In addition, bringing back a close memory may help improve quality of life. The humanoid robot Pepper has the capability to store and play music. Certain music can be selected to reconstruct a person's past. Listening to music has shown to improve the mood, memory, and comfort level of PLwD. The majority of studies summarized in this literature review have shown increased acceptance of humanoid robots amongst the tested dementia participants. The wide range of functionality for humanoid robots fits perfectly for the use of dementia care. Utilizing the capability of robots have helped both decrease the progression of cognitive impairment and care-giver stress.

There are several advantages to using humanoid robots in the care of dementia patients. The humanoid robots previously mentioned can act as a source of long-standing, continuous support. Support in areas such as psychomotor therapy can help relieve some caregiver burden. It is not easy to provide support for PLwD, and humanoid robots can take over some basic tasks of caregivers. Additionally, robots can be utilized to help give alternative methods of psychological support, such as in the area of music therapy. Listening to music can further promote cognition as music can evoke specific memories for those living with dementia. Using humanoid robots for dementia treatment has several limitations such as problems with understanding the robot, losing the robot's software connectivity, and providing the right answer to patients' questions. Furthermore, people living with advanced stages of dementia may find it difficult to understand what the robot is and how to trust it. These areas need to be addressed in the future to understand the complexity of the patients' situation and make them connected to the robot.

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