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The Pepper Robot in Healthcare: A Scoping Review

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Abstract. Humanoid robots are increasingly being used in a number of domains. This paper focuses on reviewing the use of the Pepper humanoid robot in healthcare. This robot has begun to be used in a range of settings and combines speech recognition with artificial intelligence to create meaningful interactions with users. In this paper we describe a scoping review conducted to assess the type and range of applications Pepper has been used for. The focus of the review was to determine what the uses of Pepper have been, how it has impacted healthcare and what the challenges and limitations are of using Pepper in healthcare. The results of the review indicate that Pepper has successfully been applied to an increasing range of areas which include its use in dementia care, neurodevelopmental disorders, chronic illness education, caregiver shortages as well as for cognitive stimulation therapy.

Keywords. Robotics, human factors, human-robot interaction, healthcare, education, health informatics, digital health applications, artificial intelligence

1. Introduction

Digital health is evolving and with the integration of robotics into daily human activities, we have seen significant advancements that are now emerging in healthcare. Robots are being designed and developed to interact seamlessly with people in differing settings and contexts such as the hospital, home or clinic. One of the most notable developments in the field of robotics and health informatics is the design, application and use of Pepper® the robot [1]. This scoping review aims to explore the application and implementation of the Pepper robot in healthcare. More specifically, we aim to answer the following research questions: (a) What are the uses of Pepper the robot in healthcare settings? (b) How has Pepper improved healthcare outcomes? (c) What are the challenges and limitations associated with using Pepper in healthcare?

2. Background

Pepper is a humanoid robot. The robot is considered a breakthrough in social robotics as it is designed to assist and engage with humans on an emotional level. Therefore, it is a unique tool that can be used in commercial and social settings such as healthcare [1]. Pepper is one of the first commercially available machines of its kind as it: (1) combines

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advanced speech recognition, (2) facial expression analysis, and (3) artificial intelligence to create meaningful interactions with users. Pepper incorporates voice recognition software, tactile and position sensors, microphones, force sensitive resistors and sonar capability. The robot can function in complex environments using one 3D camera and 2 HD cameras. The robot is fully programmable in C++, Python and Java. Pepper can connect directly to the Internet and includes a tablet user interface. It has 3 multi-directional wheels that allow it to move around freely through 360 degrees. Pepper marks a critical step forward in the development of empathetic robotics, setting a new standard for future robots in the healthcare industry. In healthcare, Pepper can be used to assist with tasks such as patient engagement, emotional support, and even cognitive rehabilitation. Its ability to recognize and respond to human emotions can play a significant role in improving patient experiences. Despite its promising applications, the deployment of Pepper in healthcare raises several questions about its effectiveness, practicality, and overall impact. As Pandey et al. [1] highlight, while Pepper represents a significant advancement in social robotics, the full extent of its benefits and limitations in healthcare and education remains under explored. This scoping review addresses this gap by systematically examining existing research on Pepper's use in healthcare, assessing its contributions and use.

3. Methods

A scoping review was conducted using Mak and Thomas's methodology [2]. Initially, two researchers identified keywords and databases, where the search would take place. The following keywords were used: "pepper" and "robot" and "healthcare". Following this, one of the researchers conducted a search of the academic databases: PubMed, CINAHL, Embase, PsycINFO, IEEE Xplore, ACM Digital Library, Scopus, Web of Science and Google Scholar to identify articles published in the last 10 years using the identified key words and the inclusion and exclusion criteria listed in Table 1. The articles that were returned from those searches were uploaded to Covidence®. Articles uploaded to Covidence® were then screened by the researcher's using inclusion and exclusion criteria from Table 1 in two phases. In Phase 1 the title and abstracts were screened by the researchers. The articles that remained after Phase 1 screening were read in depth. In Phase 2 each article that was read in depth and continued to fit the inclusion criteria in Table 1 was reviewed and data were extracted from the article. The data were then thematically analyzed [1].

Table 1. Inclusion and Exclusion Criteria

Criteria	Inclusion and Exclusion Criteria
Inclusion	• Studies that specifically mention the use of Pepper robots in healthcare or educational settings.
	• Articles published in journals.
	• Studies conducted in the last 10 years to ensure relevance.
Exclusion	• Studies outside the healthcare and education sectors.
	• Articles not available in full text or not in English.

4. Results

82 articles were identified from the search after duplicates were removed. Following title and abstract screening, 26 articles remained for full text review and were part of the scoping review (i.e., data were extracted from the articles to a table and the data extractions were analyzed thematically).

4.1. Thematic Analysis of the Data Extractions from the Articles

Pepper has been applied in the health areas of treatment, rehabilitation, and caregiving. One of the primary applications of Pepper in healthcare is its use in dementia care. The robot is designed to provide companionship to individuals with dementia, offering emotional support to help alleviate anxiety and fear. By engaging in social interactions through video conferencing and telephone calls, Pepper helps foster a sense of connection for patients, who may otherwise feel isolated [3]. This companionship is crucial for improving the emotional well-being of patients, particularly in care settings where human interaction may be limited. Pepper assists patients with dementia who face communication challenges. Through word reminders, picture associations, and features such as subtitles and lip movements, Pepper enhances communication for those with hearing impairments, allowing patients to express themselves more effectively despite their limitations [3].

Neurodevelopmental disorders (NDDs) such as autism spectrum disorder (ASD) and intellectual disability (ID) present significant healthcare and economic burdens for families and society. Recent advances in AI and digital technologies offer potential solutions for assessment, monitoring, and treatment of NDDs [6]. In this regard, Pepper has been employed as part of an innovative application of social robotics, where the robot is connected to the OpenAI system (ChatGPT) to facilitate real-time dialogue. Unlike traditional dynamic generative systems, this integration allows for interactive conversations between the robot and patients, especially individuals with ASD, enhancing their emotion recognition and cognitive skills such as problem-solving [4-7]. By incorporating AI, visual stimuli, and interactive robotics, this approach offers a method for supporting the neurodevelopment of individuals with ASD [4,6].

Social robots like Pepper are being considered as educational tools for healthcare settings. One specific application involves the use of Pepper in children's hospitals, where young patients with chronic illnesses, such as diabetes, must learn to manage their diseases effectively. To make the learning process more engaging and enjoyable, a game-based application was developed where diabetic children estimate the carbohydrate content of foods and meals, with Pepper providing feedback through verbal and gestural cues. Peppers built-in touchscreen which is like a tablet is particularly suitable for this type of interactive learning [8]. The children responded positively to the robot's visible and audible feedback, which was instrumental to making the learning experience more enjoyable and less stressful. This application illustrates the potential of social robots in pediatric healthcare [8].

Pepper has been used as part of audiology rehabilitation for children with cochlear implants (CI). The quality of rehabilitation services provided at hospitals, which typically require multiple weekly sessions, is a major factor in communication outcomes for children with CIs. However, frequent visits to hospitals can be a burden for families. To address this issue, home-based training with Pepper has been proposed as a solution that balances the distribution of care and promotes the child's progress. Before

developing a comprehensive home-training system, it is essential to evaluate the acceptability of using Pepper at home for both children with CIs and their families [9]. This study used questionnaires and log data to assess usability, usefulness, and engagement, finding that Pepper's ecological approach could complement traditional audiology rehabilitation while reducing the logistical burden on families [9].

The COVID-19 pandemic exacerbated existing caregiver shortages in long-term care. To address this issue, socially assistive robots like Pepper have been deployed to assist with repetitive caregiving tasks. A study conducted to assess care staff's perceptions of Pepper found that the robot was perceived as moderately usable, with a significant impact on reducing staff workload [10]. Personalization was a key factor in the robot's usability, and care staff indicated a willingness to use the robot regularly. These findings suggest that socially assistive robots could play a role in long-term care facilities by performing repetitive tasks, thus allowing human caregivers to focus on more complex aspects of patient care [10].

Recent developments in middleware for social robotics have made it easier for non-experts to utilize robots like Pepper in healthcare settings. A new middleware designed for the Android platform allows for seamless control of various robots, including Pepper, through a WebSocket server and Python integration. This system supports functions such as text-to-speech, navigation, and barcode scanning, making it highly adaptable for different healthcare use cases. The research highlights the potential for this middleware, expanding the scope of social robots in healthcare [11].

Another application of Pepper is in the domain of cognitive stimulation therapy (CST) for elderly patients with Mild Cognitive Impairment (MCI) and Mild Dementia (MD). A study conducted by De Carolis et al. [12] investigated Pepper's role in supporting CST sessions for elderly patients. Over a three-week experimental program, eight participants engaged in cognitive tasks with the help of Pepper, which provided emotional and interactive support. The study found that participants frequently anthropomorphized Pepper, treating it as a human-like companion, which enhanced their engagement during the sessions. The study contributes to growing evidence supporting the use of socially assistive robots (SAR) in cognitive therapy settings [12]. The findings indicate that SAR has the potential to mitigate cognitive decline among the elderly, especially when tailored to their emotional and cognitive needs.

In their 2023 study, Coronado and colleagues [13] developed a novel system architecture designed for Pepper, allowing it to walk side-by-side with a human while holding hands. This physical human-robot interaction (pHRI) system used force estimation and object recognition to enable the robot to adjust its walking behavior based on real-time environmental inputs. The system allowed the robot to walk hand-in-hand with humans. Future research will focus on improving these systems and testing the robot with actual human participants to evaluate usability, user experience, and the potential social impact of hand-holding interactions [13].

5. Conclusions

Robots have emerged as a new healthcare tool to be integrated into healthcare settings. This is particularly the case with Pepper the robot. Pepper has been applied to the areas of patient treatment, rehabilitation and caregiving with positive outcomes. Most of this research has involved children, youth and older adults. The use of Pepper the robot has been found to improve cognitive outcomes, emotional recognition outcomes, reduce

anxiety, reduce the need for pain medication, improve diabetic control, as well as address caregiver shortages. Although there are many benefits to using this technology, there is a need to continue investigating use cases involving the technology to extend its reach and to further support healthcare activities. Current challenges include how to best integrate the technology in healthcare practice, issues around technical support and sustainability of robotic applications in healthcare. Future work could involve comparing Pepper with other robots used in healthcare as this review was limited to only one robot. Future research needs to consider the ethical, healthcare and societal implications of robots undertaking healthcare activities.

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