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The NAO Robot in Healthcare and Education: A Scoping Review

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Abstract. Humanoid robots, designed to resemble the human form, are increasingly becoming an integral technology used in healthcare and education. This paper focuses on the NAO robot, which is engineered with advanced capabilities such as speech recognition, facial expression analysis, and complex motor functions. These features enable NAO to interact with humans more naturally and intuitively. The NAO robot's versatility allows it to assist in therapeutic settings, enhance learning experiences, and provide emotional support. This scoping review describes the ways in which NAO robots' have developed for their application and implementation in healthcare and education from a human factors perspective. Findings revealed an increasing range of applications of the robot in healthcare for supporting well-being management, social communication with children, engagement and learning about health, as well as monitoring and supporting healthcare for the elderly and the frail.

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

1. Introduction

Humanoid robots are increasingly being developed and implemented for use in healthcare (e.g., NAO®) [1,2]. Humanoid robots can be defined as robots, whose body (or its parts) look like the entire human body, a collection of human body parts or a single body part such as an arm or leg [3]. Over the past few decades, significant advancements have been made in developing robots capable of interacting with humans across various settings and contexts [4]. Humanoid robots such as NAO are increasingly used in healthcare. NAO was initially developed by Aldebaran Robotics followed by SoftBank Robotics. NAO is a highly versatile robot [4,5]. NAO can detect its surroundings, understand human speech, recognize human gestures, and even express emotions using body language and facial expressions [5]. Yet, even as NAO robots are being integrated into healthcare, little is known about the range of applications of this technology in differing healthcare settings and contexts. To understand the current level of NAO robot development and implementation into healthcare from human factors perspective, the authors conducted a scoping review to better understand the ways in which NAO robots are used.

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2. Background

NAO robots are highly expressive and interactive. They are designed with features that make them suitable for use by diverse applications. NAO's key attributes include a humanoid form, the ability to recognize and respond to human speech as well as facial expressions. NAO also has high levels of programmability and customizability. NAO's features support effective human-robot interaction (HRI). HRI includes communication, collaboration, data collection, and social interaction between humans and robots. The success of NAO is closely tied to factors such as its physical design, sensing, perception capabilities, and modes of communication and interaction. Research suggests that these factors shape human perceptions and attitudes towards robots, as well as their effectiveness in healthcare and educational settings. Such research is important to the development, implementation and adoption of robots by humans [4-5].

3. Methods

A scoping review was conducted to examine the application of NAO robots in healthcare and education, focusing on the current state of the literature. The scoping review followed the five-step framework outlined by Mak and Thomas [6]. A comprehensive search was performed using the Web of Science (Clarivate®) database which includes Medline®, CABI® and BIOS® [7] and IEEExplore®. Articles selected for further review were required to be relevant to the application of NAO robots in healthcare and education. Keywords used in the search included 'NAO robot,' 'healthcare,' and 'education.' Peer-reviewed publications addressing interaction, communication, and engagement were identified and uploaded to Covidence® for subsequent screening and review [8]. Duplicate articles were removed. The researchers then reviewed the titles and abstracts of each publication using the inclusion and exclusion criteria outlined in Table 1 to remove irrelevant and unrelated studies. The full text was then reviewed. A table was created to extract the following data: author, year of publication, purpose, participants/subjects, setting, methods and findings [6].

Table 1. Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
• NAO robot	• Editorials
• Healthcare	• Paper-based tool
• Education	• Not in the English language
• Interaction	
• Communication	
• Engagement	
• Peer reviewed	
• English Language	

4. Results

A PRISMA flow diagram was generated to document the screening (See Figure 1).

4.1 PRISMA Diagram

The results from the PRISMA diagram and the data extraction review from Phase 1 are summarized below (see Figure 1). A total of 32 records were initially identified. After removing 5 duplicate records, 27 records proceeded to title and abstract screening based on the inclusion and exclusion criteria. This screening resulted in the exclusion of 13 records, with 14 selected for full-text retrieval. Of these 14 records, 4 were excluded for not focusing on the NAO robot in healthcare, leaving 10 records available for full-text review (see Figure 1: PRISMA Diagram).

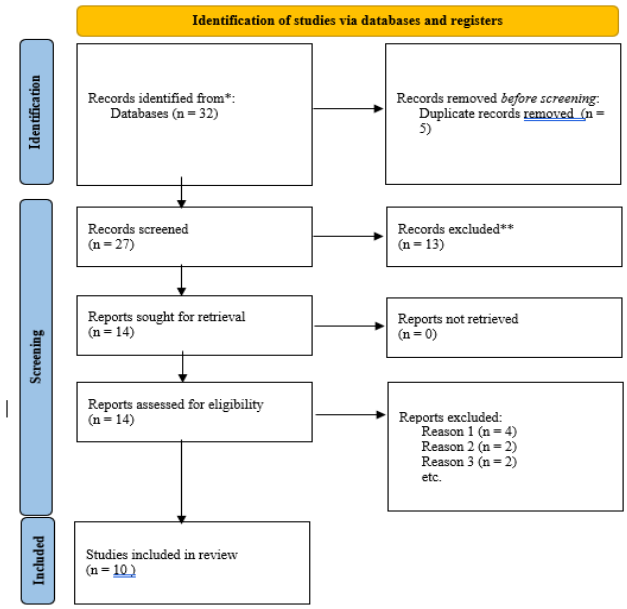

Figure 1. PRISMA Diagram.

4.2 Thematic Analysis of the Data Extractions from the Articles

The next stage of the scoping review involved thematically analyzing the data extractions. NAO mimics human behavior and interactions with patients in a manner that closely resembles real human interaction. In theory, these robots could complement or even replace human caretakers for some activities [9]. For example, social robots are increasingly being used in healthcare settings to engage children in collaborative treatments aimed at improving health-related outcomes [10].

To illustrate, NAO has been used to support diabetic youth. According to Robinson and colleagues, adolescence is a critical period for learning how to manage Type 1 diabetes. The period is often marked by sub-optimal glucose levels and a failure to meet recommended targets, leading to adverse events arising from poor glycemic control. To address this, the researchers integrated Motivational Interviewing (MI) into the NAO

robot [10]. The research showed that robotic delivery of a motivational intervention, using mental imagery-based techniques, could help adolescents reduce their intake of high-energy foods and drinks, while also boosting their confidence and motivation to make dietary changes over an 8-week period [10].

Social robots have the potential to offer both technical distractions and social support for children. For instance, they could be used to enhance children's well-being during hospitalization or to occupy them in waiting rooms and reduce anxiety involving medical procedures. Additionally, studies have shown that when children interact with social robots during blood draws, experience significantly less pain and distress [11].

NAO has also been found to help build relationships with children [2]. Researchers identified that NAO may be able to introduce clinical empathy in the context of patient care. Clinical empathy is associated with several positive health outcomes so this is particularly important for children, who rely on non-verbal communication to engage others [12]. Clinical empathy enhances children's ability to interpret others' emotions and states during interactions. Data shows that a significant majority (81.5%) of children found it easy to recognize NAO's emotions, underscoring its effectiveness in fostering empathetic connections [2].

Feng et al. found that individuals with autistic spectrum disorder can learn to interact with humanoid robots such as NAO and engage in essential social-communicative behaviors. NAO's multiple sensors enable various levels of interaction with humans. For example, during games, NAO asked participants a few simple questions and instructed them to make eye contact while answering [13]. These sessions were recorded using both external cameras and NAO's built-in camera [13].

In the fields of education and healthcare, child-robot interactions are becoming increasingly prevalent. Social robots are used in education not only to enhance learning, such as mastering multiplication tables and acquiring a second language, but also to improve emotional outcomes, including reducing learning-related anxiety. A study by Nagy et al. found that NAO robots assist children with autism in understanding classroom instructions and increasing their engagement in learning activities [14]. Interactions between children and robots in educational settings with autism have been shown to enhance both cognitive and affective learning processes [14].

NAO plays a significant role in elder health. Olde Keizer et al. found that social robots can be effective in monitoring and supporting the health of frail older adults. Instrumental touch is an expected interaction modality for NAO, enhancing its role in providing medical assistance and improving perceptions of the robot [15]. Elderly participants have reported that touch-based interactions with NAO are more comforting and strengthen the bond with caregivers compared to verbal communication [15].

5. Discussion and Conclusions

This scoping review investigated the use of NAO robots in healthcare and education. The review revealed several key themes. The review highlighted the NAO robot's interaction capabilities and its potential uses in these fields. Equipped with multiple sensors, the NAO robot offers comprehensive environmental perception, which enhances healthcare delivery and supports therapy through interactive training. Additionally, NAO robots can help to manage children's anxiety while increasing their engagement and motivation surrounding specific health topics. NAO's facial recognition and communication abilities enable it to understand and respond appropriately to human

emotions. Moreover, the programmable nature of the NAO robot allows for customization based on specific needs. The scoping review concludes that NAO robots possess significant potential in both healthcare and education, warranting further research and development.

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