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Humanoid Robot: Application and Influence

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Abstract

Objective: In this paper, we have summarized the influence of human age and gender on acceptance of humanoid robot and discuss the effect of robot's appearance, physical movement, and usability on human behavior and their perspective towards a robot. The paper also studies the factors that affect a user's trust towards a humanoid robot and observes the possible application and users of humanoid robots in diverse domains.

Background: Application of humanoid robot has been well established in the field on healthcare and education. It has been frequently used to treat autistic children and has been able to reduce distress level in children who have cancer and cerebral palsy. In the domain of education, humanoid robots have been able to enhance student participation but not learning.

Methodology: Systematic literature review was conducted to gather information about humanoid robot application and its influence on human behavior and productivity.

Results: Effect of gender and age were found to be the most influential factor that defines a user's perspective towards the humanoid robot. Moreover, robot's appearance and gaze determine users' acceptance and trust towards robots.

Conclusion: Children and Older adults prefer humanoid robots. The deterministic behavior of humanoid robots improves autistic condition among children. People with less social networks treat robots as their companion. Humanoids have influenced human productivity in the field of education and healthcare.

Key Points:

- The Social connectivity of individual influences their perspective towards the use of a humanoid robot. Lonely individuals, especially autistic children and older adults prefer an assistive humanoid robot.
- The appearance of the robot influences user acceptance and trust. Users irrespective of their age, gender, and social and health status preferred robots with human-like appearance.
- Application of humanoid robot to treat autism among children has been useful.
- Trust on a humanoid robot depends on the criticality of the situation a user finds herself or himself. Trust factor increases with a decrease in the confidence of a user in any quantitative decision-making situation.
- Humanoid robot in the education domain has been effective in increasing student participation.

Keywords: Assistive technology; Healthcare; Education; Human behaviour

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Introduction

Humanoid Robots have been helping human beings in various capacities. Humanoid robots have been broadly used in the field of Healthcare, Education, and Entertainment; Moreover, Humanoid robots have been playing diverse roles in the human environment such as interacting socially and helping people as a friend, teacher, assistant, and remote healthcare provider.

This paper performs a systematic literature review of humanoid robots to study its applications, benefits, and limitations in various fields.

Specifics

This paper classifies humanoid robots based on their application. In the following section, the paper state the research questions that need to be addressed and conducts a literature review to study the same and describes the findings. In the discussion and conclusion, this paper highlights factors influencing human-robot interaction and lists some of the key takeaways at the end.

Humanoid Robots

Definition

A humanoid robot is a robot that not only resembles human's physical attributes especially one head, a torso, and two arms but also should have the capability to communicate with humans and other robots, interpret information, and perform limited activities according to the user's input. Humanoid robots are equipped with sensors and actuators. These robots are typically pre-programmed for determined specific activities.

Based on typical applications, humanoid robots can be categorized into Healthcare, Educational and Social humanoid robot. Healthcare humanoid robots are used by patients at home or healthcare centers to treat and improve their medical conditions. These robots either require a human controller or are fully preprogrammed to assist patients. Educational humanoid robots are for students and are used in education centers or home to improve education quality and increase involvement in studies. These robots are typically manually controlled robots. Social humanoid robots are used by individuals or organizations to help and assist people in their daily life activities. These robots are commonly preprogrammed to perform mundane tasks and are also known as assistive robots.

Research questions

There have been many instances where robots have been used to reduce human error. Manufacturing, healthcare, hospitality, education, and many other fields use robots in some form; Moreover, the application of robots in the military, manufacturing, and research is well-established. A humanoid robot is a specific robot that is in its developing phase. Humanoid robots can perform several human-like physical activities; however, its effectiveness, especially in the field of healthcare, education and social, is a concern. In this study we are focusing on the following questions:

What is the effect of human age and gender on the application of a humanoid robot?

When do people accept and trust a humanoid robot?

This paper conducts a literature review and based on published literature, addresses the stated questions.

Literature Review

This paper conducts a systemic literature review of a humanoid robot and summarizes all the research and studies conducted in the last ten years. The search for this review was limited to ACM Digital Library, ASME Digital Collection, BIOSIS Citation Index, CINDAS Microelectronics Packaging Material Database, Cite Seer, Computer Database, Emerald Library, Energy & Power Source, Engineering Village, IEEE Xplore, MEDLINE, OSA Publishing, PubMed, Safari Books Online, Science Direct, Sci Finder, SPIE Digital Library and Springer Database. The search was conducted using "Humanoid Robot," and all papers containing the phrase anywhere in the content were considered for further analysis. This keyword "Humanoid Robot" gave 12,261 results that included books, articles, conference proceedings, newspaper articles, dissertations, retracted papers, technical reports, audiovisuals, government documents, statistical data sets, and images.

Selection/ Exclusion criteria

As mentioned above, our focus was restricted to papers published between 2008 and 2018. Further constraints such as material type and language were set. Papers published in the English language was listed, this left us with 3,392 papers to investigate. Once the primary basic search was done, we shortlisted the paper based on their title and then on their abstract.

Title based selection

The first scan of these papers was done by reading the title only. Any papers consisting of a technical report and robot manufacturing were rejected. All the article that discussed usage, application, open source software for humanoid robots and or literature review of humanoid robots were selected. Any paper that only talked about android or computer application was also not selected. We selected 368 papers.

Abstract & finding based final selection

The selected papers were again scanned to make a final list of papers. This was done by reading the abstract of each paper. We preferred any paper that has any connection with education, healthcare, and social. Fifty-eight papers were shortlisted for this study.

Results

Application of humanoid robots has been significantly used in healthcare and education domain. Majority of the study involved minors and senior citizens; moreover, economic feasibility was not tested in any study involved in this paper.

The following section briefly discusses the influence of age, gender, and other experimental setups on the behavior of

humans towards humanoid robots and their application in various domains.

Healthcare humanoid robot

Users and healthcare practitioner have appreciated the advantage of advanced surgical robots. However, our study highlights the application of humanoid robots and their roles in healthcare today. In addition to surgical robots, healthcare humanoid robots have been successfully helping people in disease management, pain relief, pediatric healthcare assistant, and physical therapy. The role of healthcare robots can be broadly classified into the clinical and non-clinical application.

In Clinical setting, humanoid robots have been used to assist patients who have cerebral palsy [1], and pediatric cancer [2]. To study the influence of human-robot interaction on user attention two children of age 9 and 13 who have cerebral palsy were exposed to NAO robot under four different interactive situations. The experiment aimed at improving patient coordination, truncal balance and motor function [1]. The first interaction was general introduction round where children and robot verbally communicated with each other. In this situation, the subject had a tough time understanding the robot and required the help of a therapist; thus, it increased positive interaction between the subject, robot, and the therapist. This was aimed to enhance a child's social adaptability [1]. The second, third, and fourth interaction session was an imitation round which aimed at improving a child's lower leg balance and function. In this setup, the children had to imitate movement, lift one leg movement and kick a ball movement of the robot [1]. No improvement was observed during this setup; however, the children developed a positive interaction with the humanoid robot [1].

The crucial responsibilities of the robot in clinical healthcare domain are distress minimization [3], remote monitoring [4], and interacting with the patients [1-3,5]. To measure the effect of a humanoid robot in pain and distress minimization, "Face Pain Scale-Revised" [3] approach was taken during vaccination of children in a clinical setup. The pain level of the children during the injection shot was measured through their facial expression and behavior such as crying or muscle tension. Children felt more pain during vaccination in the absence of a robot in the clinic [3].

Moreover, a study on the effect of a humanoid robot on anger, anxiety, and depression level has also been significant. To study the effect of a robot on anger and anxiety and difference between "social robot-assisted therapy" [2] and psychotherapy children who have cancer were given therapy session using a robot and a human psychotherapist. The group assisted by the robot had eight sessions in which the robot played different roles such as a doctor, chemotherapist, nurse, cook, ill kid and other. In these sessions, the robot interacted with the children and explained to them the role of each character in a story form to reduce their anger, depression, and anxiety. Post the experiment a questionnaire was used to assess anger, anxiety, and depression level of the children. It was observed that the robot-assisted group had lower anxiety, depression, and anger than that of the controlled group. Humanoid robots were successful in minimizing anger, anxiety, and depression [2] among cancer patients. Humanoid robots also enhanced joint attention between the patient and the therapist [6].

The patients treated using humanoid robots were mostly children around the age of 85 years [4]; 5 to 6 year [3]; 7 to 12 years [2]; 5 to 14 years (Malik, Yussof, Hanapiah, Rahman, & Basri 2015); 9 & 13 years [1]; Moreover, a supervisor or controller was always present to monitor and control the humanoid robot.

Non-Clinical healthcare have significantly contributed to Autism Management followed by Diabetes Management [7] by performing activities such as playing games [8,9] greeting, singing, dancing, hand movement, blinking, interacting with the patients [2,3,9-12]. Robots also measured blood pressure [13-15], and asked questions, played quiz with the patients and [7,16] monitored and helped patients with medical assistance [4].

Effect of using robots in autism management and treatment has been highly effective and appreciated. Humanoid robots can be developed to facilitate social skills for autistic children [17], thus, can improve patient's autistic behaviour [12,18-20].

Most of the research conducted on autistic patients using humanoid robots aimed at enhancing their social skills. Gaze is a crucial medium that enables social communication. It also affects acceptance, preference, and obedience among human beings [18]; However, excessive gaze might impose a threat, superiority, and anger [18]. To study the effect of task difficulty and gaze on user's trust on robots fifty-two university students were selected for the experiment in which they had to engage in the "shell game" [18] with the robot. The game was conducted in three different levels of difficulty. A mixed 3 × 3 design was employed to study the behaviour of the subjects at Averted gaze, constant gaze and situational gaze [18] for the easy, medium and hard difficulty level of the game. Here, the independent variable was the three levels of gaze and game difficulty level. Averted gaze in which the robot never looked at the participant, constant gaze during which the robot continuously looked at the participant and situational gaze when the robot looked at the participant only when he/she gave a wrong answer. It was observed that with an increase in difficulty participant's trust increased.

Use of humanoid robot have significant influence on communication, social behavior and joint attention of autistic patients [21,22] but did not influence any collaborative behavior among patients [9]; However, playing with human adult enhanced collaboration among patients [23].

To study the effect on joint attention a therapy session was conducted in a school playroom setting. Students in this experiment used a humanoid robot, and the interaction was recorded. In, this study the robot directed students to perform physical activities such as touching head or look towards the window. The study measured the number of times the participants responded correctly to the robots. The experiment was run under two condition, with prompting and without prompting. Improvement in joint attention initiation and response were noticed; however, the relevance and contribution of prompting were unclear.

Humanoid robots helped patients to learn more about autism management [24]. The ability of the humanoid robot to evoke human-human interaction along with its impact on learning was analyzed in a study conducted by Cost in 2015. The experiment was classifieds into four sections: "familiarization, pre-test, practice, and post-test phase". In this experiment, the participants had to identify their different body parts as per asked and directed by the robot. In this study, it was observed that the participant's response increased in the "post-test phase" and; thus, the learning ability of the participant were increased after therapy using a robot. The study, thus, showed the effectiveness of a humanoid robot in the domain of child education and healthcare,

Humanoid robots have also enhanced diabetes and diabetes management [7]. The benefactors of the humanoid robots in autism and diabetes management were mostly children [4,25] of age 6-7 years [22], 6-9 years [24], 8-12 years [7], 5-10 years [26], 6-8 years [23], 7-12 years, 5-13 years [9] and 7-13 years [12].

Education humanoid robot

Use of computer and e-learning in the field of education have been performing well and have successfully increased the access to education worldwide. However, the recent trend in education domain is towards the application of humanoid robots. Humanoid robots are now becoming an essential component of education domain as these robots have the capability to reason and analyze situations logically to support human learning and are also better than computer agent [27] and more engaging than the virtual agent [28]. Comparison between a projected robot, a collocated robot, and an on-screen agent has been a relevant concern in the domain of education and e-learning. To study the impact of a computer agent, on-screen projection, onscreen projection of a robot and a physical robot on the social behavior such as engagement, disclosure, influence, memory, attitude etc. were measured to find that collocated/physical presence of robot-enhanced participant's engagement [27] with the subject; however, it had no effect on social behavior; Moreover, there was no significant difference found between onscreen robot, and a collocated robot. Unlike other studies, this showed that learning ability was minimum using a collocated robot. Humanoid robots have been known for teaching language [16,29] hands-on engineering [30], nutrition [31], mathematics [9], general science [32] as well as helps students in spelling learning, storytelling [33] and participate in memory games. Robots have been performing the role of a teaching assistant and games partner of children [16,34-37].

In most of the studies, humanoid robots were used along with a human teacher or a controller. The educational humanoid robots have been used for various sections of education and have addressed wide range of students such as preschool kids [37,38] primary school kids [3,16,36-39] junior high school students [34] and undergraduate engineering students [40]. Students responded positively to the robots. Positive effect on learning [38] was observed along with higher classed participation [32]. Increase in a student's creativity [41], curiosity, and knowledge recall rate [42] was observed.

Socially assistive robot

Social robots or socially assistive robots (SAR) are known as assistive robots, and their application is burgeoning especially among elderly people and hospitality industries. Social robot assists human beings in their daily life and replaces human activities at hospitality industries. At the domestic level, social robots have been doing well. Retired older adults or autistic patients mostly use the robots. These assistive robots act as a companion [43,44] for both children and elderly individuals. Among children, social robots have been known for their ability to entertain [23] and play games [45]. Importantly, autistic children prefer to spend more time with a robot [12] since robots are more predictive and less intimidating than human beings [46].

In this domain, most of the study emphasized the effect of age, gender and appearance of the robot on acceptance, social behavior of the user, and trust towards the humanoid robot. Children and elderly users have a diverse opinion about the appearance of a robot. Some preferred humanoid whereas, some liked machine-like appearance [10]. Since humanoid robots look like a human, they are more relatable and a better fit for companionship [10,47]. According to a literature review, people relate male humanoid robots as more intelligent in decision making whereas; female robots were perceived to be good at nursing and caring activities [10].

Humanoid robots can also evoke the feeling of care and enhance awareness of social behavior [45]. Consecutively, according to a survey and interview conducted by Broadbent in 2009 older people opted for robot staff to help them in daily life activities such as making a phone call, control appliances, remind medications and appointments. In the study by Broadbent in 2009, several pictures of different types of robots were shown to the workers and residents of a nursing home. Most individuals preferred a humanoid robot with all human-like physical features. Even the size of the robot impacted their perception. Elderly users opted for a medium sized robot with light, bright color; However, there was no influence of the robot's gender on the users [47]. The ability of a social robot to detect fall and serious medical condition of the user was highly appreciated; Moreover, assistive robots also play an important role in elderly care; they remotely observe the user and communicate with their care providers, thus, further reducing nurse workload [48]. **Table 1** below summarizes the main findings from the literature review.

The **Table 2** following lists the typical application and features of commonly used humanoid robots.

Discussion

The application of humanoid robots specially NAO [49].

Use of humanoid robot has been significant in several domains [50]. It has been successfully implemented in the field of healthcare, education, and social. **Figure 1** below shows the application of humanoid robots in three broad domains.

Majority of the research is focused on healthcare. **Figure 2** below shows that humanoid robots were used mostly to treat

Table 1 The main findings from the literature review.

Author	Year	Paper	Finding	Robot	Method	Participants	Domain
Taheri, Meghdari	2018	Human-Robot Interaction in Autism Treatment: A Case Study on Three Pairs of Autistic Children as Twins, Siblings, and Classmates	The decrease in Autism severity, improvement in social behavior and participation	NAO	Experiment with the robot (games with the robot), questionnaire, interviewing parents	n=6; age=6 to 7 yr.	Healthcare
Charron, Lewis	2017	A Robotic Therapy Case Study: Developing Joint Attention Skills with a Student on the	Improved communication skills	NAO	Speech therapy session with a robot which was recorded	n=1; age = 8yr	Healthcare
Miyachi, Iga	2017	Human-Robot Communication with Facilitators for Care Robot Innovation	The paper certified that humanoid robots could substitute caregivers	PALRO	Experiment (recreations and health gymnastic activities with robots), feedback from participants	n=13/38; age: 70 to 87 yr./ 65+ yr.	Healthcare
Bakster, Ashurst	2017	Robot education peers in a situated primary school study: Personalization promotes child learning	Personalized (concerning behavior; adjusted to the user) robots are accepted more than a regular robot, the Positive effect on learning using both types of robots, Personalized robots generate higher learning	NAO	Experiment and Questionnaire	n=59; age: 3 yr	Education
Erich, Hirokawa	2017	A Systematic Literature Review of Experiments in Socially Assistive Robotics using Humanoid Robots	Most used Robot is NAO ; Humanoid Robots are used in Teaching; Assisting; Playing and Instructing; Most of the robots where controlled manually; Most robots could: react to touch, point at body parts, sing and dance; Robots always had motors; rarely with actuator; Most studies did not require a sensor, but the camera and microphone were frequently needed	KASPAR; NAO; BANDIT; ROBOTA; ROBOVIE R3	Literature review	(----)	Healthcare, Education
Stanton, Stevens	2017	Don't stare at me: the impact of a humanoid robots' gaze upon trust during a cooperative human-robot visual task	Females did not trust robots when they steadily gazed at them, but they trusted the robot for situational gaze, participants trusted the robot as game difficulty level increased, participants with low confidence about their answer, trusted robots more.	NAO	Experiment, game at three levels of difficulty	n=52; age: 22.5 yr. (mean)	Social
Thellma, Silvervarg	2017	Folk-Psychological Interpretation of human vs. humanoid robot behavior: exploring the intentional stance towards robots	People find robots to take undesirable actions more than human, user associates negative behavior to robots, users believe robots do everything intentionally.	Ellis	Questionnaire,	n=90; age:24 yr (mean)	Social
Vandemeulebroucke	2017	How do older adults experience and perceive socially assistive robots in aged care: a systematic review of qualitative evidence	Participants gave more attention to SAR's ease of use, user like interacting with the robot, Human looking SAR were preferred		Literature review, wizard of Oz, Thematic synthesis by Thomas and Harden in 2008	n= 23 studies; age: 65 yr. (mean)	Social
Baxter	2017	Robot education peers in a situated primary school study: Personalization promotes child learning	Children showed significantly increased learning in personalized condition	NAO, Sandtray touch screen	classroom experiment, robot taught three subjects, picture recall, math, and spelling	n=59; age:7 to 8 yr.	Education
Henkemans, Bierman	2017	Design and evaluation of a personal robot playing a self-management education game with children with diabetes type 1	It improved health literacy in children. The learning activity was entertaining, engaging and motivating.	NAO (personal and neutral)	Experiment: introduction, quiz	n=27; age: 7 to 12 yr.	Healthcare, Education

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Llamas, Conde	2017	May I teach you? Students' behavior when the lecture by robotic vs. human teachers	Students liked the robot more than human teachers.	Baxter	Experiment; observing the reaction and behavior of the students while interacting with the robot.	n=210; age: 6 to 16 yr.	Education
Alemi, Ghanbarzadeh	2016	Clinical Application of a Humanoid Robot in Pediatric Cancer Interventions	A robot can be used as an assistant in cancer treatment. Humanoid robot was found to be useful in teaching children about their afflictions. Robots instructed the children about methods to confront their distress level.	NAO	Children interacted with robot, Children responses such as anger, and depression was measured using questionnaire	n=11; age: 7 to 12 yr.	Healthcare
Yun, Kim	2016	A robot-assisted behavioral intervention system for children with autism spectrum	Robots assisted behavior intervention system was developed that is capable of facilitating social skills for children with Autism	iRobiQ	Experiment;	(---)	Healthcare
Gaudiello, Zibetti	2016	Trust as an indicator of robot functional and social acceptance. An experimental study on user confirmation to iCub answers	Users trust robots functional knowledge (weight, color, height, etc.); Users did not trust robots social knowledge (most important subject, an important object, etc.); Collaborative interaction with robot did not affect the users' trust	iCub	Experiment, Questionnaire	n=56; age: 19 to 65 yr.	Social
Pennisi	2016	Autism and Social Robotics: A Systematic Review	NAO is the most widely used the robot in Autism therapy, participants with Autism had better performance in robotic condition than in human condition	NAO, KASPAR, Pleo, Tito, The TOUCHPAD, Bioloid Robot, RBB, Flobi, Sony Aibo ERS-7, GIPY-1, Ifbot, Parlo, Keepon, Probo, Romibo, FACE, POL, Robota, LEGO Mindstorms NXT, Rofina.	A systematic review, (electronic database search)	n= 29 studies	Healthcare
Yi, Knabe	2016	Experiential Learning in the Development of a Darwin HP Humanoid Educational Robot	Using humanoid robot motivates college students to be interested in engineering, hands-on experience with robot helps in better learning	Darwin-HP	Hands-on experience with the robot. modified design of the robot with the help of a supervisor	n=65; age: undergraduates	Education
Hashim	2016	Humanizing Humanoid towards Social Inclusiveness for Children with Autism	Teachers demanded to see other school using humanoids in the classroom before they accept one, Robots must be personalized especially for autism patients.	NAO	Literature review, interviews with teachers & parents	age: Parents and teachers	Healthcare
Huijnen	2016	Mapping Robots to Therapy, and Educational Objectives for Children with Autism Spectrum Disorder	NAO is used in the highest number of articles, and Robots focus on very set of objectives. However, ASD treatment requires to cover a wide range of domains	NAO, other robots (Robota, Probo, Keepon, Isobot, Tito, GIPY-1. KASPAR, Ifbot, Labo-1)	the focus group, and systematic literature study	n =53; age: adults	Healthcare
Rosi, Dall'Asta	2016	The use of new technologies for nutritional education in primary schools: a pilot study	The robot's presence along with the teacher did not affect the learning improvement.	NAO	Experiment: robot intervention with the teacher; Questionnaire	n=112; age:8 to 19 yr.	Education

Aziz, Moganan	2015	Autistic Children's Kansei Responses Towards Humanoid-Robot as Teaching Mediator	Children got more involved when robot talks and makes hand gestures.	NAO	Experiment: interaction with the robot. (greeting, singing, etc.); Observation using Kansei checklist	n=3; age: children	Healthcare
Rahman, Hanapiah	2015	Use of Humanoid Robot in Children with Cerebral Palsy: The Ups and Downs in	Robot's movement encourage imitation learning, socializing and motivate the children	NAO	Experiment: Interactive session with robot	n=2; age: 9 & 13 yr.	Healthcare
Malik, Yussof	2015	Human-Robot Interaction for Children with Cerebral Palsy: Reflection and	The robot improved treatment efficiency by initiating joint attention between child and therapist.	NAO	Experiment: Interaction with the robot.	Age: 5 to 14 yr.	Healthcare
Mann, MacDonald	2015	People respond better than computer tablets delivering healthcare instructions	Robots are more trusted than tablets; Appearance of robots determines the user's responses to healthcare interactions; Increased speech with robots; More emotion and relaxation with robots; Participants thought that robot was accurate in measuring blood pressure than a tablet	Yujin Robot's iRobiQ, ASUS Google Nexus 7 Tablet	Interaction with robot and questionnaire	n=65; age: 19 to 62 yr	Healthcare
Alemi	2015	Clinical Application of a Humanoid Robot in Pediatric Cancer Interventions	The robot can be used as assistant in cancer treatment, and the Humanoid robot was found to be useful in teaching children about their afflictions, Robots instructed the children about methods to confront their distress level.	NAO	Children interacted with robot, Children responses such as anger, and depression was measured using questionnaire	7-12 yr.; 11 children	Healthcare
Barakova	2015	Long-term LEGO therapy with a humanoid robot for children with ASD	Interaction with robots induced more creativity among children.	NAO	12 sessions with the robot and student LEGO designing experiment	n=6; age:8 to 12 yr.	Education
Shiomi, Kanda	2015	Can a Social robot stimulate scientific curiosity in classrooms?	It encouraged the children to ask about science by initiating conversations about class topics. However, the robot did not increase any curiosity in the subject. Some students asked more questions to the robot.	Robovie	Experiment	n=144; age: 4th to 6th-grade student	Education
Li, Lizilcec	2015	Social robots and virtual agents as lecturers for video instruction	Participants who saw the inset video of the actual lecture replaced by an animated human lecturer recalled less information than those who saw the recording of the human lecturer. However, when the actual lecturer was replaced with a social robot, knowledge recall was higher with an animated robot than a recording of a real robot.	NAO	Experiment: online video course	n=40; age: 18 to 25 yr.	Education
Ioannou, Andreou	2015	Pre-schoolers' interest and caring behavior around a humanoid robot	Kids can easily interact and play with the robot. Children also took care of the robot when he falls.	NAO	Experiment: Playing with NAO	n=4; age:3 to 5 yr.	Social
Huskens, Palmen	2015	Improving Collaborative Play Between children with autism spectrum disorder and their siblings: the effectiveness of a robot-mediated intervention based on LEGO therapy	The robot intervention had no significant effect on the children. It did not improve the collaborative behaviors of children	NAO	Experiment: play Lego with robot	n= 6; age: 5 to 13 yr.	Healthcare
Costa, Lehman	2014	Using a Humanoid Robot to Elicit Body Awareness and Appropriate Physical	Children did not lose interest throughout the session. Games with robots increased children's learning.	KASPAR	Experiment: Familiarization with robot-> practice task -> perform	n=8; age: 6 to 9 yr.	Healthcare

Kachouie	2014	Socially Assistive Robots in Elderly Care: A Mixed-Method Systematic Literature Review	SAR enhances the well-being of seniors and minimizes nurse's workload.	AIBO, Bandit, Healthbot, iCat, Ifbot, Nodding Kabochan, Nabaztag, NeCoRo,	Systemic review (Cochrane Handbook for Systematic Reviews of Interventions)	n= 86 studies	Social
Boboc	2014	An educational Humanoid Laboratory Tour Guide Robot	Robots can be used to attract students to educational institutes	NAO	The robot as a tour guide	(---)	Education
Freidin, Belokopytov	2014	Acceptance of socially assistive humanoid robot by preschool and elementary school teachers	Teachers are ready to accept humanoid robots to serve as an interactive tool in education, and Teachers believed robots do not evoke negative vibes	NAO	UTAUT and TAM model to check acceptance of robot. The questionnaire, followed by an experiment where participants interacted with the robot	age: preschool & elementary school teachers	Education
Broadbent, Kumar	2013	Robots with Display Screens: A robot with a More Humanlike Face Display Is perceived To Have More Mind and a Better Personality	A robot with a human-like face is preferred, trusted and considered to be social	People-bot Healthcare robot (face displayed on a screen)	Experiment: Robot measured user's blood pressure then user rated their experience with the robot	n=30; age: 22 yr (mean)	Healthcare
Henkemans, Bierman	2013	Using a robot to personalize health education for children with diabetes type 1: A pilot study	Children loved robot. They talked more to the robot. They learned more about diabetes. Children mimic the robot.	NAO	Experiment: Robots asked a question to the children	n=5; age: 8 to 12 yr.	Healthcare
Broadbent, Kumar	2013	Robots with Display Screens: A robot with a More Humanlike Face Display Is perceived To Have More Mind and a Better Personality	A robot with a human-like face is preferred, trusted and considered to be social	People-bot Healthcare robot.	Robot measured user's blood pressure then user rated their experience with the robot	n=30; age: 22 yr. (mean)	Healthcare
Henkemans, Bierman	2013	Using a robot to personalize health education for children with diabetes type 1: A pilot study	Children loved robot; They talked more to the robot; They learned more about diabetes; Children mimic the robot	NAO	Robots asked a question to the children	n=5; age: 8 to 12 yr.	Healthcare/ Education
Kamide, Kawabe	2013	Development of a psychological scale for general impressions of humanoid	Females > Male (robot humanness and familiarity); Middle age females ranked utility to be highest, and young age ranked it least; Old males and females think robots are useful; Adolescent males like robots' utility more than adolescent females; No one liked android	Robovie, wakamaru, enon, ASIMO, HRP2, HRP4C, M3-Neony, CB2, Repliee, Geminoid, Geminoid F	Experiment, introduction to robots	n=900; age: 10 to 70 yr.	Social
Beran	2013	Reducing children's pain and distress towards flu vaccinations: A novel and effective application of humanoid robotics	Interaction with robots during flu vaccination resulted in less pain and distress	NAO	robot interacted with the child while the nurse gave a vaccination, robot gave high-five, introduction and talked about the child's interest	n=57; age:5 to 6 yr.	Healthcare
Freidin	2013	Kindergarten social assistive robot: First meeting and ethical issues	Children reacted positively with the robot, paid high attention, showed a high degree of enjoyment.	Kindergarten Social assistive robot	robot playing with children,	n=11; age: kindergarten students	Education

Kim, Suzuki	2013	Comparative Study of Human Behavior in Card Playing	No difference in engagement; While playing with the robot, people gazed at the robot more than on the table	Genie	Experiment: playing the game first with human, then with the robot.; Questionnaire	n=10; age: 22 to 29 yr	Social
Wainer, Dautenhan	2013	A Pilot Study with a novel setup for the collaborative play of the humanoid robot KASPAR with Children with Autism	Children with Autism were more interested and entertained by a robot partner, but the show more collaborative action while playing with a human adult.	KASPAR	Experiment	n=6; age:6 to 8 yr	Healthcare/Social
Cabibihan, Javed	2013	Why Robots? A survey on the roles and benefits of social robots in the therapy of children with autism	The paper categorizes the robots as DIAGNOSTIC AGENT, PLAYMATE, BEHAVIOR ELICITING AGENT, SOCIAL MEDIATOR, SOCIAL ACTOR, and PERSONAL THERAPIST.		Literature Survey	(----)	Healthcare
Beran, Serrano	2013	Humanoid robotics in health care: An exploration of children's and parents' emotional reactions	Parents wanted robots beside their children while flu vaccination was given. The child smiled more when the robot was present. The child more memory of the robot than of the needle	NAO	Experiment; Interviewing parents	n=57; age: 4 to 9 yr	Healthcare
Freidin	2013	Storytelling by a kindergarten social assistive robot: a tool for constructive learning in preschool education	Children enjoyed interacting with the robot.	Kind SAR	Experiment: Robot did physical action and pre-recorded storytelling	n=10; age: 3 to 3.6 yr.	Education
Wood, Dautenhan	2013	Robot-mediated interview- how effective is a humanoid robot as a tool for interviewing young children	Interview using robot lasted longer; Children looked at the robot more than the human; Children were willing to interact with a robot for an interview in the same way they wanted to interact with a human, the information exchange was also similar	KASPAR	Experiment: Interviewing the children (both human and robot interviewed); Questionnaire	n=21; age: 7 to 9 yr	Social
Ismail	2012	A robot-based intervention program for autistic children with humanoid robot NAO: initial response in stereotype behavior	Less stereotype behavior was observed with robot interaction than in regular classroom	NAO	Experiment: Interaction between the robot and the children were observed, NAO introduced itself, hand movement, play song, and eye blink; song and hand movement	n=12; age: children	Healthcare
Bacivarov	2012	The paradigm of utilizing robots in the teaching process: a comparative study	Humanoid robot resulted in 61%Higher participation, 80%Higher performance, and creative thinking, 0.81 Higher social impact, 100% Course attendance, and zero drops out rate	Robonova-1, SIMROBOTO (simulator), ROBOBASIC v2.72; ROBOremocon v2.5; ROBOScript v2.6 (programming the robot)	Teaching using actual robot and simulator	n= 15; age: primary school students	Education
Ismail	2012	A robot-based intervention program for autistic children with humanoid robot NAO: initial response in stereotype behavior	Less stereotype behavior was observed with robot interaction than in regular classroom, Stereotype behavior can be reduced and improved further by better modules in a robot-based intervention program	NAO	The interaction between the robot and the children were observed, NAO introduced itself, hand movement, play a song and eye blink; song and hand movement	n= 12	Healthcare

Kahn, Kanda	2012	Robovie you will have to go into the closet now: children's social and moral relationships with a humanoid robot	Children developed a relationship with the robot. Children would like to play with the robot at a free time or when they feel lonely	Robovie	Robot-human interaction, general interaction verbal, played the game, followed by an interview	Healthcare/ Social+J90: K103	Social
Shamsuddin, Yussof	2012	Humanoid Robot NAO Interacting with Autistic Children of Moderately Impaired Intelligence to Augment Communication Skills	Children showed a decrease in autistic behavior; the robot was able to engage the children. Lower autistic traits were observed during the HRI session than compared to the in-class setting.	NAO	Experiment: Interaction with the robot	n=5; age: 7 to 13 yr.	Healthcare
Back, Kallio	2012	Remote monitoring of nursing home residents using a humanoid robot	Humanoid robots can be used as remote monitoring of nursing home residents, and the robot can autonomously perform the checking of the resident's room and provide a caregiver with real-time images and a voice connection to the room.	NAO	Experiment: tested a prototype in three nursing homes	n= 10 to 22 (each nursing home); age: 85 yr. (mean)	Healthcare
Chin, Wu	2011	A Humanoid Robot as a Teaching assistant for Primary Education	Physical robot helped students understand more; students feel relaxed with the robot than a teacher; Robot and teacher sync was good; All students want robots in their class	IDML TOOL (with the humanoid robot and computer screen)	In-class use of robot and Questionnaire	age: Primary school students	Education
Chang, Lee	2010	Exploring the Possibility of Using Humanoid Robots as Instructional Tools for Teaching a Second Language in Primary School	Students enjoyed learning and responded positively with the robot as teaching assistant; the Preferred robot in storytelling mode; the Preferred robot in oral reading mode; the Preferred robot in cheerleader mode	Sapien	Experiment	n=100; age: primary school students	Education
Han	2010	Robot-Aided Learning and r-Learning Services	Robots are more responsive in teaching than e-learning; Robots can initiate learning and active than e-learning; Unlike a computer, robots can have physical interaction with students; Robots can build a relationship with the user; Robots enhances communication between children and parents.; Teacher and student both prefer robots in education	iRobiQ, Tiro,	Literature review	age: Primary school students	Education
Bainbridge, Hart	2010	The Benefits of Interactions with physically present robots over video displayed agents	Participants were more likely to fulfill requests from physically present robot; They allowed more personal space	Nico	Experiment: Interaction with the robot, physically and over video	n=65; age: 24 yr. (mean)	Education
Broadbent, Tamagawa	2009	Retirement home staff and residents' preferences for healthcare robots	Older people demands robot care provider; People prefer a robot to staff; People prefer robot with a display screen; Robots that can detect fallings, control appliances, remind medication, making phone calls are accepted easily; Users prefer human-like structure in their robot	Hopis and In-Touch Telemedicine Robot	Questionnaire and face to face interview,	age: 60 yr.	Healthcare and social
Kuo, Rabindran	2009	Age and gender factors in user acceptance of healthcare robots	Males have a more positive attitude towards robots than females, can be a potential customer; Users demands, more interactive and better voice from robot; Middle-aged and older people responded in the same way	Peoplebot with display monitor (Charles)	Experiment (blood pressure measurement)	n=57; age: 40 to 65yr and >65yr	Healthcare
Powers, Kiesler	2007	Comparing a computer agent with a humanoid robot	Participants spent the most time with collocated remote and remote robot than computer agent, and women confessed more than men did, users remembered most information from the agent, users found robots more useful.	Agent on computer monitor; Agent projected on a large screen; remote robot projected on a large screen; the collocated robot in the room	interview with robot and agent, questionnaire	n=113; age: 26 yr (mean)	Healthcare

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Robins, Dautenhahn	2004	Effects of repeated exposure to a humanoid robot on children with autism	The child mimics the robot. The child corrected his/her mistake while mimicking the robot's movement. Eyegaze, closeness to robot, touch, and imitation increased with time	Robota	Longitudinal research,	n=4; age: 5 to 10 yr	Healthcare
Robins, Dautenhahn	2004	Effects of repeated exposure to a humanoid robot on children with autism	Children corrected his/her mistake while mimicking the robot's movement, Eye gaze, closeness to robot, touch, and imitation increased with time.	Robota	Longitudinal research	n=4; age: 5 to 10 yr	Healthcare
Bruce, Nourbakhsh	2002	The Role of Expressiveness and Attention in Human-Robot Interaction	People paid more attention when the face was present and tracked them	RWI B21; Human face on robot display screen (VIKIA: the face of a young woman)	Experiment, (robot asking a question)	(-----)	Social

Table 2 List of typical application and features of commonly used humanoid robots.

Robots	Application	Control	Robot Action	Actuators	Sensors
KASPAR	Teach children with Autism to identify their body parts	Mixed (manual and autonomous)	Reacting to touch	Motors and speakers	Tactile
KASPAR	Teach children with Autism	Autonomous	Reacting to touch	Motors	Tactile
NAO	Assist school staff	Manual	Singing, dancing, playing, explaining	Motors and speakers	Microphone
NAO	Assist older people	Autonomous	Healthcare assisting activities	Motor, Speaker, and Projector	Microphone, Camera, external sensor network
NAO	Entertainment	Manual	Playing, talking, gesturing	Motors and Speakers	None
NAO	Education	Mixed	People detection, talking	Motors and Speakers	Camera
NAO	Deliver letter	Manual	Walking, bowing, waving	Motors	None
NAO	Train Autism victim's attention skills	Mixed	Asking a question and moving naturally	Motors and Speakers	Camera network
NAO	Interacting with Autism child	Manual	Sitting, moving, dancing, speaking	Motors, Speakers	None
NAO	Hospitality (hotel reception)	Autonomous	Looking at guests, reading	Motor, Speaker (Text to Speech)	Kinect
Bandit	Assist post stroke (healthcare)	Autonomous	Giving instructions, feedback, motivating	Motors, Speakers	Wire Puzzle
Robota	Interact with Autism child	Manual	Move as per instructed	Motors	None
Robovie R3 & NAO	Teach sign language to the child	Mixed	Indicating sign	Motors, LED, Speakers	Kinect, camera, microphone
NAO	Teach physical exercise to reduce back pain	Manual	Demonstrate exercise	Motors	None

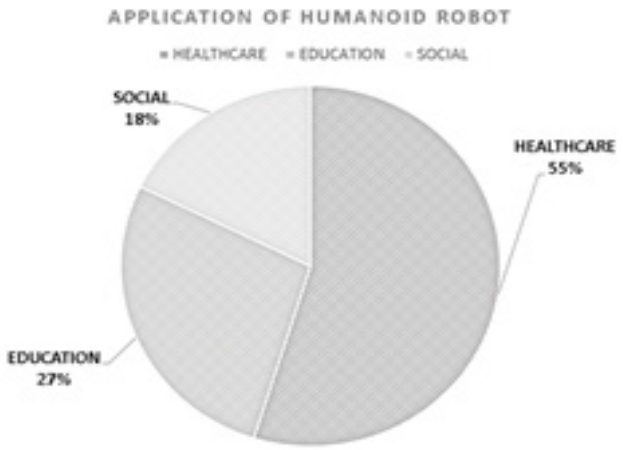

Figure 1 Application of Humanoid Robot.

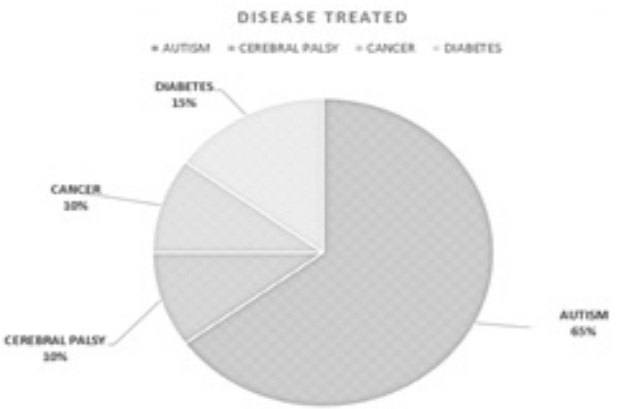

Figure 2 Diseases treated using Humanoid robot.

autism (65%) followed by diabetes (15%), cancer (10%) and cerebral palsy (10%). Humanoid robots improved autism severity (Shamsuddin & Yussof, 2012) and enhanced social behavior [21], communication skills among children; Moreover, use to humanoid robots enhanced collaborative behavior, learning capacity among autistic children and interaction with robots made them feel entertained and comfortable (Kim, Chung, & Jung, 2018). Apart from successfully treating autism, humanoid robots yield positive results in educating patients with diabetes management skills [7], minimize stress in pediatric cancer patients. Patients who have cerebral palsy got encouraged by interacting with humanoid robots. Usage of the robot also enhanced treatment efficiency by initiating joint attention between the patient and the therapist [6].

Figure 1, developed based on the literature review, shows the proportion of work dedicated to healthcare, education, and social assistance using humanoid robots and highlights [51] the influence of humanoid robots [52] in the field of healthcare, moreover, the potential of a humanoid robot to become a personal healthcare assistant has been projected in Miyachi and Iga's recent work [53]; however, some limitations exist especially to treat autistic children. To better manage autism, humanoid robots must have a diverse set of objectives and should be personalized based on the user. **Figure 2**, also developed based on the literature review, shows that about sixty-five percent of the work using a humanoid robot within the healthcare domain have been directed towards managing autism.

Application of humanoid robots in the field of education has also been promising. Studies have shown the positive influence of robots on education; moreover, humanoid robots have acted as a tour guide within the college campus [54]. **Figure 3**, developed based on the literature review findings, shows the most analyzed aspect of humanoids in education. From the literature review, it was found that application of a humanoid robot-enhanced the interaction of participants within a classroom setting, however [32,41] no significant increase in learning rate were observed.

The study conducted by Barakova in 2015 focused on analyzing the effect of using collocated robot and simulation on a student's enthusiasm. During the experiment with both robot and simulator, performance such a dropout rate, class attendance, task completion rate, creative thinking, and social impact were measured. All the measures were higher when working with a humanoid robot than that of a simulator; moreover, according to the questionnaire developed by Marina and Freidin in 2014 in their study, teacher, and students both preferred usage of a humanoid robot in the classroom setting. The study measured anxiety, attitude, adaptability, trust, and other, using questionnaire. The study also observed that factors such as social presence and social influence are not relevant to determine a humanoid robot's acceptance.

Moreover, students enjoyed and preferred the presence of humanoid robot in class [55,56]. Few studies have shown significant impact on the learning ability of the student using humanoid robots, but the presence of humanoid robot ensures higher class attendance, promotes creative thinking and increases subject curiosity. **Table 3** below shows the user's requirement from a typical humanoid robot specifically in the domain of private healthcare.

The users have appreciated the role of humanoid robots in the field of healthcare and education. Contrastingly, people's attitude towards social or assistive robots varies significantly. Children and

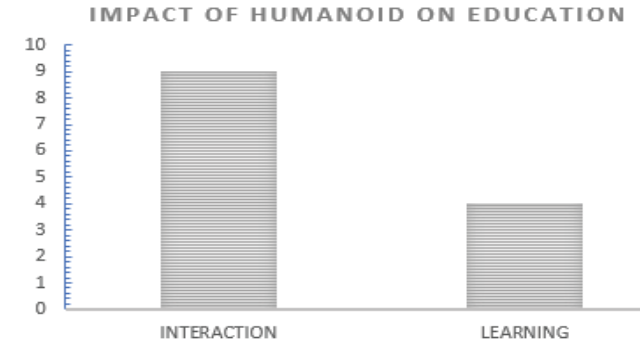

Figure 3 Humanoid's Impact on Education.

Table 3 Tasks for Home Healthcare Humanoid Robots.

Tasks	Percentage (Users asked for these features)
Measuring BP, Body Temperature, Pulse, and Heartbeat irregularities. Sending the report to the doctor.	30.43%
Connecting with a family doctor remotely	30.43%
Medicine reminder	30.07%
Providing remote video connection for the doctors	28.97%
Detecting health trouble, people lying (heart-attack) and call emergency help	27.87%
Communicating to patient-doctor from time to time to ensure everything is ok	27.13%
Ensure medications are taken at the proper dose	27.13%
Reminding doctors to take care of the patient	26.03%
Helping in speech therapy	26.03%
Improving cognitive disability of the patient	25.67%
Helping in occupational therapy	25.30%
Helping in baby care management	24.57%
Helping in wound management and tube feeding	24.20%
Monitoring injuries	23.83%
Entertaining the patient	23.47%
Helping in mental therapy	22.73%
Helping in social skill and autism therapy	22.00%

elderly users prefer robots and have less resistance towards the application of humanoid robots than that of middle-aged users. Trust and acceptance of humanoid robots were affected by its appearance [57], gaze, and functionality. According to a survey by Alaiad, people felt that using humanoid might be a threat to their privacy [58].

Humanoid robots were preferred more than general assistive robots; even people gave more attention to humanoid robots which are user-friendly. Adult female users' trust decreased when the robots constantly gazed at them; however, users with lower confidence had more trust towards the robot. Humanoid robots were trusted on their functional knowledge such as weight, size, color, and other quantitative measures, but users did not trust on social and logical knowledge such good, bad, and other qualitative measures given by the robot. People also believe that humanoid robots take undesirable actions intentionally and are more prone to make an error. Unlike adult users, children were not concerned about the robot's utility. They enjoyed the company of humanoid robot and treated them as a friend. Children were willing and able to interact with the humanoid robot easily. Old males had high concern about a robot's functionality more than adolescent or females. Users want the humanoid robots to measure blood pressure, body temperature, connecting with doctor remotely, reminding tasks, entertain, helping in baby care management, lifting heavy, detect fall, control home appliance, housekeeping, making phone call and many other things.

Conclusion

The application of humanoid robots is crucial in the field of healthcare, education and as a social robot. In all these domains, most of the research is focused on the effect of using the humanoid robot, user acceptance and trust on the robot. It can be observed from the existing literature that opinion of the people towards the use of humanoid robot varies from individual to individual. A user of different age, gender, and health condition perceive the usage and importance of humanoid robots differently. The appearance of the robot was found to be a crucial factor affecting user acceptance and trust; moreover, robot functionality and gaze also affected user preference towards humanoid robot application.

Although many studies have been conducted to analyze the usage and effectiveness of humanoid robots, we still need more research in this field. As future research, the influence of incorporating a humanoid robot into the Project Leonard as an assistant to care managers in order to enhance disease and care management effect must be addressed [59].

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