

Humanoid Robot Acceptance: A Concise Review of Literature

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Abstract—As a relatively new area of study, the field of humanoid robotics is a fascinating topic of discussion. This concise literature review analyzes and discusses the different papers and studies from within the field of humanoid robot acceptance. We look at the different types of robots used in each study, the roles of participants, the cultural acceptance across different countries, and the trends in methodology and technology over the course of the 21st century. Overall, we found that the approach towards the acceptance of humanoid robots must be specialized by taking into account the user’s age, gender, culture, and experience with modern technology, among other factors, due to the varying attitudes towards humanoid robots that accompany different human characteristics.

Index Terms—humanoid robots; acceptance, robot acceptance, humanoid robot interaction, robotics and healthcare, global context

I. INTRODUCTION

Computers surround almost every aspect of our lives, and it can often be impossible to go throughout the day without coming across at least one computer. For most people, interacting with a computer has become an easy task and is often sought out. People use laptops to write papers, make calls on their cell phones and even use smart vacuums to keep their homes clean. However, when computers are given faces, voices, and even bodies, people are more likely to retract from the interaction. The “uncanny valley” is a concept that describes the goal of making robots appear humanlike where our liking for them rises until we come to a valley [1]. According to the School of Informatics at Indiana University, “uncanny” is described as “the eerie feeling attributed to human-looking robots and animated characters” [2]. The uncanny valley often results in hesitation from users when they are asked to interact with something that appears very human. While the use of social robots with dementia patients has been shown to reduce loneliness and agitation [3], the apprehensiveness that comes with the interaction between a robot and a user often makes the use of robots in settings such as nursing homes and care facilities difficult.

This literature review provides an important, modern, and general overview of the trends surrounding humanoid robot acceptance. There have been similar literature reviews in previous years; however, these reviews have a more narrowed focus. For example, the literature review by Góngora et al.

[4] analyzes and discusses papers in the field of social robots used for people with aging and dementia. Another example is Lu et al. [5] which focuses on the literature surrounding service robots, customers, and service employees. From the search criteria used, we found that there has not been a recent general overview of the trends surrounding humanoid robot acceptance, thus the purpose of developing this literature review.

Technology acceptance has changed significantly since the turn of the 21st century. With society’s transition to a more technology-dependent world, more researchers have been studying ways to increase levels of acceptance of humanoid robots. Across the world, different countries currently experience different levels of technology acceptance by their general public as robots have been integrated in various ways by different cultures.

II. BACKGROUND ON ROBOT ACCEPTANCE

Many modern robots have features that are seen as frightening and uncanny, especially in the eyes of users who are not familiar with advanced technology. Many people describe robots to be “missing something” because even though they can appear to be extremely human-like, they are still missing something that makes robots different from humans. This is often why even the best robots can still appear frightening [6]. Robot acceptance plays an essential role when integrating robots into healthcare, education, work environments, and everyday society. When humanoid robots are not accepted by users, the technology cannot be used to its full potential. In places such as nursing homes and other healthcare facilities, robots can be very useful as they provide a patient with attentive care and safety along with more freedom to live independently. Examples may include a robot fetching water for a patient or a robot leading a patient in a physical therapy session. However, developing the capability of robots is not the only obstacle. Creating a robot with specific features and characteristics that are comforting and reassuring to the user has proven difficult in several studies [7-12]. In a healthcare setting, where trust plays a key aspect in the relationship between a patient and a caregiver, human or robot, the patient must feel comfortable with their caregiver [13-16]. Developing

an emotional connection between a human and a robot is essential to achieving robot acceptance.

Previous studies have shown that building relationships with robots is vital for robotic acceptance. In the study by Kalmer Allouch [14] a zoomorphic (animal-like) robot was studied in the homes of participants for ten days to help improve the overall well-being of participants. The rabbit-like robot, Nabaztag, would talk with participants and ask them about their activities, their feelings, as well as their exercises. The results show that enjoyment and playfulness are not important for the acceptance of the Nabaztag robot and that relationships did not necessarily form from these factors. However, hedonic factors are determined to be important for building a relationship with the robot. With the study's constraint of ten days, time may have played a role in strong relationships not being built between the user and the robot.

In another study, video clips of manufactured robots were shown to elderly participants who were then asked to complete a questionnaire about the design and implementation of socially assistive robots. The results showed that the humanoid robot, Pepper, was generally preferred over the other two humanoid robots, Ishiguro and Erica. The Ishiguro and Erica robots had much higher levels of human likeness than Pepper. The questionnaire showed that participants felt a "feeling of discomfort and eeriness" when the robots resembled too closely to a human, leading to the refusal of daily use of the robot [17].

The uncanny valley is not limited to the elderly population. In a survey about robot acceptance and adoption, 36 out of 40 randomly selected individuals between the ages of 17-40 years old expressed concern about robots [11]. The main reasons for apprehension generally stem from the technology, the robot's ability to emotionally interact with users, as well as security and privacy concerns. While humanoid robots are becoming more and more popular, much hesitation still surrounds them. Due to this issue, many studies of humanoid robot acceptance have shifted focus in recent years.

III. METHODS

The goal of this concise literature review is to analyze past and present research papers and studies to determine the trends found within the field of humanoid robot acceptance. Technology, trends, findings, participants, and levels of acceptance from users were analyzed in depth to determine how this field of research has changed and where it may lead in the future. Through the use of Google Scholar, 50 research papers were found under the search criteria "humanoid robot acceptance". We initially found 130 papers through this search criteria, however, only papers that were freely available were considered. Papers published between the years 2000 and present-day were considered, however, the earliest paper included in this review was published in 2004, due to the field being quite newly researched. Another requirement for eligibility was that the paper must be written in the English language.

IV. GLOBAL CONTEXT

Different regions focus on different uses for robots as well as different robotic research topics. For example, countries such as China and Japan tend to focus on service and healthcare robots as these societies generally have higher levels of acceptance towards robots [6, 12, 18, 19]. The aim of these countries is to use robotics in day-to-day life to make things easier for people, whether that be through everyday tasks, such as aiding in shopping or household chores, or through aiding in healthcare services, such as the monitoring of vitals or completing repetitive or tedious tasks. Western countries, on the other hand, are still focusing on the acceptance of robots in their societies [6, 9, 12, 20, 21]. Since these countries are fairly new to robotics, their populations are not as comfortable interacting with robots and this kind of advanced technology. Therefore, the research on robotics in these countries focuses much on the general acceptance of robots.

Nomura has conducted several studies on the cultural differences in the social acceptance of humanoid robots across Japan and the UK. In one of Nomura's studies, participants from the UK showed more negative attitudes toward interaction with robots than Japanese participants [20]. The study also showed that participants from Japan and participants from France held opposing views when discussing unemployment that may be caused by the growing field of robotics. A similar study by Nomura, Syrdal, and Dautenhahn [12] shows similar results with respect to the social acceptance of robots in Japanese and UK cultures. Kaplan [6] supports these findings in their study focusing on the cultural differences in the acceptance of robots. The study found that in Western countries, society is both fascinated and afraid in the presence of robots and new technology. Society in Eastern countries on the other hand does not appear to be largely disturbed by the presence of robots.

Research also shows that media often plays a large role in how robots are perceived by society. In a 2015 study surrounding the perception of robots by Japanese and Australian citizens, Japanese participants were found to generally perceive robots to be more intelligent and safer in comparison to the views of Australian participants. This difference is perhaps due to how robots are displayed in these different countries [18]. Politeness can also affect how robots are perceived by societies. Different cultures have different traditions and ways of expressing gratitude and likeness. A study of Arabic and English native speakers found that the politeness level of the robot had a significant effect on how the participants viewed the robot [22]. Supporting this, Trovato et al. [19] found that people generally prefer a robot that is culturally close to them. An example would be a robot expressing similar gestures and ways of speaking to the participant's culture. Overall, we found that different cultures utilize robotics to their society's needs and that users become more accepting of robots when they interact with them in familiar environments.

V. PREVIOUS WORK

Over the past two decades, the research done within the field of robotics has grown immensely, with new studies coming out at an exponential rate. Over 50% of papers within the field of humanoid robot acceptance have been released since 2016. The studies vary in their technology, participants, environment, methodology, and results. However, all of the studies have the same overall goal of learning more about the acceptance of humanoid robots.

A. Technology

While some studies use the same robot as others, these robots are often used for different purposes. The robots used in the analyzed studies include ALBIAN, ARMAR, CAVE, Charles, DB, Hala, HRP-4, iCub, Kabochan, KASPAR, KOBIAN, KOBIAN-R, Leonardo, Nabaztag, Nao, Penumbra, PeopleBot, Pepper, Robata, Robi, Robovie, Roboy, Sacarino, Sota, WABIAN-2R, and WE-4RII. Almost all of these robots are described as “humanoid robots”. While many studies used the physical robot in their experiments to interact with participants, others chose to use videos or pictures of the robots, often due to the cost of equipment or space/environmental purposes. The most common type of robot used among these studies was NAO, which was utilized in 13 studies [9, 13, 16, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32]. NAO is a humanoid robot manufactured by SoftBank Robotics. It has 25 degrees of freedom, seven touch sensors, four microphones and speakers, speech recognition, and two 2D microphones. NAO is 58cm tall and bipedal which makes it a very useful tool to use in a humanoid robotic study with limited space.

From the studies that worked with NAO, most found that participants had positive experiences with the robot. When focusing on the acceptability of robot assistance in the management of type 1 diabetes in children [13], it was found that participants appreciated when the robot would provide advice about how to handle high and low blood sugar levels. Other studies found that users often desire features such as eye contact, additional visual output, and meaningful interactions [27, 28, 30]. In comparison to other humanoid robots, many participants tend to perceive NAO as more lifelike, likable, intelligent, and safe [32].

NAO’s size makes it a very useful robot for interacting with children as well. Al-Tae et al. [13] utilized NAO to collect carbohydrate and insulin data through its sensors while the child interacted with the robot. In other studies where NAO is used alongside other humanoid robots, NAO is often proven to be a generally less intimidating robot, which makes it easy for children to interact with. In another study, kindergarten-aged children interacted with NAO while it played music and danced. The study found that exposing children to physical robots at a young age can positively affect their attitudes toward humanoid robots and increase acceptance [23].

Many of the studies used less popular robots that had different sizes, abilities, and purposes. For example, in another study focusing on children, children with autism were encouraged to practice social interaction skills through the use of the

“toy/doll” robot called Robata [33]. The robot appears like a human baby doll. The benefit of using this type of robot with children over a robot such as NAO is that Robata resembles something that many children are already familiar with. In a study focusing on elderly users, the robot called, Sacarino, asks users about their preferred characteristics of a robot. Sacarino is another humanoid robot used in both a hotel and a care facility [34]. Sacarino is beneficial to use in large spaces as it has a mobile base that allows it to navigate through its environment. NAO would not be as useful for this type of study as it has legs and feet for movement, resulting in the robot being slower and more unstable.

B. Participants and Environment

The number of human subjects to participate in these studies vary greatly from 3 to 1000 with the average number of participants being 106. While many of these studies included participants of all ages, other studies focus on a specific age group, such as children [13, 23, 33, 35, 36] or the elderly [3, 14, 15, 16, 17, 37, 38, 39]. Many of these studies take place at a university, therefore many of the participants happen to be college students in their early 20s. Other studies focus on participants of a specific culture, gender, or field of work [6, 8, 9, 21, 22, 25, 40, 41, 42, 43]. For example, in the study conducted by Latikka, Turja, and Oksanen [42], care staff and volunteers are surveyed about self-efficacy and the acceptance of robots.

Several different environments were used as testing locations for these studies. While many were virtual, gaining most of their information from online questionnaires, many of the studies conduct their experiments in real-world locations such as clinics, classrooms, professional workshops, shopping centers, long-term care facilities, hotels, and homes of participants. Many other studies conducted their experiments in a controlled laboratory setting. With most of the studies that focus on children and elderly participants, the robot often goes to their places of residence, such as a school or a nursing home as transportation for these participants can often be difficult. Throughout the analysis of these studies, we found that more researchers are beginning to focus on participants over the age of 65 years old. The need for humanoid robots in nursing homes and healthcare facilities is becoming more and more of a necessity as the elderly population steadily increases over time.

C. Trends

Over the past two decades, there have been many trends in the field of humanoid robotics. From 2004-2008, there was a strong focus on the technological development of humanoid robots [44, 45]. In 2009, the socialization of humanoid robots and peoplebots with users began [38, 46, 47], in addition to early studies on how robots can be used in nursing homes to aid in patient care and monitoring [14]. Later in 2012, researchers wanted to discover more about which characteristics of humanoid robots were preferred, such as voice, gender, gestures and emotions [26, 27, 41]. Trending in 2014,

humanoid robots began making their way out of research labs and into schools and exhibitions to be introduced to younger generations [25]. In the study conducted by Sciutti, Rea, and Sandini [35], the desired properties of a robot friend were analyzed to show that adults and children have very different opinions about what characteristics are important for social robots. The field of humanoid robot acceptance took large strides in 2015. This year resulted in more research studies focusing on the interaction with social robots. Studies began to focus on the affection, eye contact, greetings, and general interactions between users and humanoid robots [18, 21, 28, 48]. The designs for humanoid robots became more focused towards gaining the user's acceptance, rather than just accomplishing the technological task it was designed to do. Researchers tended to center their studies around integrating humanoid robots into society, such as in shopping malls, schools, and residential homes [31, 49].

Similar to 2009, 2019 once again resulted in a strong focus on the interactions between humanoid robots and elderly users. The main difference between the trend of using humanoid robots in nursing homes in 2009 vs. 2019 was that in 2009, humanoid robots were being used as tools to aid in patient care, by completing tasks such as monitoring vitals and delivering medications [14, 46, 47]. In 2019 however, humanoid robots were being used more as companions for patients within nursing homes by conversing with them, playing games with them, and helping with general care [4, 39, 42]. The following years have seen much of the same trends as more and more research studies have come out with the focus being on the appreciation and acceptance of humanoid robots by elderly users as well as the general public.

Over the years, humanoid robots have greatly advanced technologically and in their level of acceptance by users. This in part has to do with how society has become more comfortable with technology in general as well as how the design of these humanoid robots has changed to be more comforting to users. These humanoid robots are more inviting to interact with. In the early years of development of humanoid robots, one of the main features was that robots often did not have faces. In the robots that did have faces, it was common that the face did not move, often resulting in the eerie feeling described as the uncanny valley. In the early 2010's, humanoid robots started to be developed with more welcoming faces that were more comforting to users, resulting in more willingness to interact with robots. Humanoid robots were developed to be more mobile around the year of 2014. With many being equipped with wheels or two separate legs, humanoid robots became more user friendly as they were able to accomplish more tasks. In the most recent years, humanoid robots have become so humanlike, that some have features such as artificial skin and hair.

D. Results

The topics of the studies analyzed in this literature review generally fit into one of six categories: elderly people, children, different genders, different cultures, levels of anthropomor-

phism, and user attitudes. With the elderly population, it was found that while they do not tend to like high degrees of human likeness [17], evidence does not suggest that the elderly is necessarily afraid of robots [39]. Ruf, Lehmann, and Misoch [16] found that older adults enjoy the company of humanoid robots and are motivated to participate in physical activity, however as many of these studies took place over a short period of time, there were generally no substantial changes in attitude and conditions across the studies [14]. In the studies focusing on children, it was found that children almost always have a positive view on humanoid robots. Children and adults have very differing opinions on humanoid robots and what characteristics are important for an interactive robot [35]. When children are exposed to robots at a young age, their attitudes towards robots can be positively affected [23]. Teachers also show interest in using robots in classrooms with children to use as an interactive teaching tool [25]. From the studies that focused on the biological gender of the user and/or the perceived gender of the robot, it was found that people are generally more accepting of humanoid robots if they share the same gender as the user [41]. When using humanoid robots in healthcare, men tend to have a more positive view on healthcare robots than women [46]. However, the perceived gender of the robot played no role in the amount of trust that a user has in the robot [7]. Cultural differences play a large role on societal opinions of humanoid robots. Eastern countries tend to be more accepting of humanoid robots compared to Western countries [6]. It was found by Trovato et al. [21] that people from different cultures will anthropomorphize a robot more, and prefer it more, if the robot appears culturally close to them.

As the opinions about humanoid robots vary from person to person [8], the user's attitude plays a large part in determining how they will view a humanoid robot. Found by Destephe et al. [10], a user's attitude is the main influence that leads to the feeling of the uncanny valley. However, as a user's familiarity with a robot increases, participant often feel a more meaningful interaction [27]. The overall result found is that the lack of knowledge about robots plays one of the most influential roles that affect the level of acceptance towards a humanoid robot [11].

VI. DISCUSSION

The goal of this concise literature review was to analyze the current studies and papers in the field of humanoid robotics. We found that children and adults have radically different attitudes toward using and interacting with humanoid robots. While adults are concerned about a humanoid robot's ability to emotionally interact with users [11], children are excited to interact with humanoid robots. The study by Martin et al. [29] found that in studying the nature of children's altruism, children were highly likely to help a robot when it appeared that help was required. Cultural factors also play a large role in how humanoid robot acceptance must be achieved. In a study analyzing future psychologists' acceptance of humanoid robots, participants from Italy and the UK were given the

UTAUT questionnaire. From the results, it was found that Italians gave positive reviews while participants from the UK gave negative reviews [9]. Due to the differing opinions from the different cultural groups, different routes would need to be taken in order to achieve robot acceptance.

The limits of the studies within this review include time, participants, and experiment costs. The field of robotics is an expensive one, and due to that fact, many research groups are constrained to the type of robot that they have the means to afford. This often results in researchers not working with the most ideal machine for their study. Participants and time also prove to be a limitation as human subjects are required for all studies surrounding humanoid robot interaction. Many of these studies require large amounts of time in order to study long-term effects. The inability to find large numbers of people willing to dedicate great amounts of time is one of the biggest factors that result in the limitation of long-term evidence. Thus, this literature review is limited by the constraints of studying robotics in general.

The trends within these studies show that the field is moving away from analyzing the physical characteristics of the robot and focusing more on the emotional connections that can be developed between the robot and the user. In a study that focused on the acceptance of shopping center robots, participants described the humanoid robot as polite, friendly, and appealing [49]. When users are able to develop an emotional connection through a robot's level of politeness, a stronger connection can be achieved between the user and the robot. A study analyzing humanoid robots in shopping malls found that if a robot appeared to be expressing "troubling" behavior, the robot is more likely to attract more passersby [50]. Behavior reaches the user on an emotional level which results in a stronger connection between the user and the robot. Future research is expected to follow similar trends of focusing on the emotional development between users and robots. In order for this to occur, aspects such as communications and psychology are likely to merge into the field of humanoid robot acceptance.

VII. CONCLUSION

As robotics is a fairly new field that is still being intensively studied, people are only just becoming accustomed to interacting with humanoid robots. The overall result of this concise literature review is that the approach towards the acceptance of humanoid robots must be specialized by taking into account, among other factors, the user's age, gender, culture, and experience with modern technology due to the varying attitudes towards humanoid robots that accompany different human characteristics. We found that current research in this area mainly focuses on the acceptance of humanoid robots in service, business, and healthcare settings, however, different cultures have different levels of acceptance. Robotic technology has advanced greatly over the past two decades and has made great strides in the societal acceptance of robots. We are currently seeing more studies about the development of emotional interactions between humans and robots. These

current findings show that people are generally beginning to feel comfortable with having robots in their households and within society. Current studies appear to be aimed toward the emotional acceptance of humanoid robots whereas past studies focused on the physical acceptance of robots. In order to result in users developing a more trusting relationship with a robot, future studies should follow the trend of focusing on developing emotional relationships between users and robots. The results of this literature review suggest that different ages, genders, and cultural groups have greatly varying opinions on the importance of humanoid robots and how they should be used in society and that adapting to each person will require specialized development. Therefore, researchers should place more focus on these factors in order to individualize approaches to acquiring humanoid robot acceptance across different groups.

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