Exploring the Role of Human-Robot Interactions, within the Context of the Effectiveness of a NAO Robot

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Abstract: The NAO robot has been widely used in various settings, from education and healthcare to entertainment and research. The effectiveness of the robot largely depends on its ability to interact with humans in a meaningful and engaging way. This paper explores the role of human-robot interaction in the effectiveness of the NAO robot. We review the literature on human-robot interaction and highlight the key factors that contribute to successful human-robot interactions. Then we discuss the specific features of the NAO robot that facilitate or hinder effective human-robot interactions. Finally, we present some recent studies that have investigated the impact of human-robot interaction on the effectiveness of the robot in different settings. Overall, our analysis suggests that effective human-robot interaction is essential for the successful implementation of the NAO robot, and that further research is needed to better understand the dynamics of human-robot interaction and its impact on the effectiveness of the robot.

Keywords: social robot; NAO; human-robot interaction; education; HRI

1 Introduction

Over the past few decades, the field of robotics has made significant advances in the development of robots that can interact with humans, in a variety of contexts. One such robot is the NAO robot (Figure 1), a humanoid robot developed by the French robotics company Aldebaran Robotics (now part of Softbank Robotics).

The NAO robot has been used in various settings, from education and healthcare to entertainment and research. However, the effectiveness of the NAO robot largely depends on its ability to interact with humans in a meaningful and engaging way. In this paper, we explore the role of human-robot interaction in the effectiveness of the NAO robot. Human-Robot Interaction (HRI) is an interdisciplinary research field that aims to develop a deep understanding of the communication, cooperation and relationships between humans and robots. In recent years, HRI research has made significant progress, including advances in perception, cognition, navigation and communication technologies that have facilitated more effective human-robot collaboration [1] [2]. One of the main goals of human-robot interaction is to enable humans and robots to work together effectively to perform various tasks. HRI research focuses on several areas, such as social interactions, collaboration, learning and adaptation [3]. Researchers use a variety of methods to study HRI, such as laboratory experiments, user evaluations and simulation modelling [4].

2 Related Work

Human-robot interaction (HRI) is a multidisciplinary field that encompasses various aspects of human-robot communication, collaboration, and social interaction. The success of HRI depends on a range of factors, including the robot's physical design, its sensing and perception capabilities, its communication and interaction modalities, and the context of interaction. Some of the key factors that contribute to successful HRI include robot expressivity, anthropomorphism, social presence, and adaptivity. These factors have been studied extensively in the literature, and there is growing evidence that they play a crucial role in shaping human perceptions and attitudes towards robots, as well as the effectiveness of HRI in different domains.

NAO robot features: The NAO robot is a highly expressive and interactive robot, with a range of features that make it suitable for a variety of applications. Some of the key features of the NAO robot include its humanoid form factor, its ability to recognize and respond to human speech, its facial and gestural expressivity, and its programmability and customizability. These features have been instrumental in the NAO robot's success in various settings, but they also pose some challenges for effective HRI. For example, the anthropomorphic design of the NAO robot may lead to unrealistic expectations of its abilities and limitations, while its limited sensing and perception capabilities may hinder its ability to understand and respond appropriately to human cues.

This humanoid robot created by SoftBank Robotics, has been gaining attention in the field of education due to its potential to enhance student engagement and promote active learning. However, there are also several challenges that need to

be addressed when it comes to using NAO robot in education [5]. Here are some of them:

Cost: The NAO robot is an expensive technology, which can limit its accessibility to many educational institutions. The cost of the robot itself is only part of the equation, as schools may also need to purchase additional software and equipment to make the most of the robot's capabilities.

Technical challenges: Using NAO robot requires technical expertise, which may be beyond the capabilities of some teachers and educators. The robot's programming language and software can be complex, and it may take some time for educators to learn how to use the robot effectively.

Limited functionality: While NAO robot has a wide range of capabilities, its functionality is still somewhat limited compared to other educational technologies. For example, the robot's mobility is limited, which may restrict its ability to interact with students in certain ways.

Ethical concerns: As with any technology that collects data, there are ethical concerns associated with using NAO robot in education. Some educators may be hesitant to use the robot if they are unsure how student data will be used, stored, and protected.

Limited research: While there is growing interest in using NAO robot in education, there is still relatively little research on its effectiveness as a teaching tool. As a result, it can be difficult for educators to determine whether the investment in the robot is worth the cost and effort.

Despite these challenges, the NAO robot has the potential to revolutionize the way that students learn and engage with technology. With further research and development, it is possible that many of these challenges can be overcome, making NAO robot a valuable tool for educators in the years to come.

Figure 1
NAO robot

Several recent studies have investigated the impact of human-robot interaction on the effectiveness of social robots in different settings.

For example, a study by Kollar and Vanya found that human-robot interaction cannot be just pessimistic, negative, or only optimistic, maximally accepting and supportive. Robots are constantly appearing in different areas of social life, such as work, private life, public places, offices, the defence. Their conclusion from empirical research is that in the next 10-15 years, a generation will emerge that will socialise with robots, making human-robot interaction increasingly close and emotionally meaningful [5]. As the mobile phone becomes part of everyday life robots will become more and more like human companions [6].

Another study by Tasevski et al. shows the importance of talking for therapy robots and the need for recordings of children-robot interactions to validate this requirement [6]. Not NAO, but also a social robot MARKO (Figure 2) can talk to people by itself, which is important for making children like the robot and use it for therapy. To prove that talking is important for therapy robots, they recorded interactions between children with movement problems and MARKO in a realistic therapy setting. A human-controlled MARKO and made it talk in a therapeutic way in their research process. Their results has been found that the children responded well to MARKO and were motivated to do therapy exercises. MARKO's positive effects go beyond just social interaction, as it also helps children with therapy-relevant nonverbal actions [8].

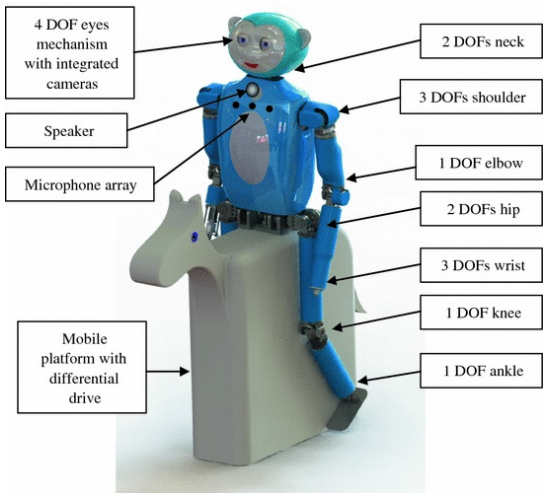

Figure 2
The Human-like robot MARKOt

Sungjin Lee et al. found in their study that robots can be effective tutors for learning English as a foreign language, particularly in improving pronunciation and speaking skills. In their study, the authors investigated the effectiveness of a robot-assisted language learning activity using the robot in improving the pronunciation of English as a foreign language among Korean elementary

students. They found that the robot-assisted activity led to significant improvements in the children's pronunciation and speaking skills [4].

Another study by Cabibihan et al. in 2013 found that NAO robots can help children with autism to understand classroom instructions and improve their engagement in learning activities [5].

Interaction between children and robots in education has been found to enhance both cognitive and affective learning processes, however, there remain some issues that require further investigation. One such challenge is the problem of interaction disorders between children and robot tutors, as the current user interface is mainly based on visual touchscreens. This model is designed to be used for children aged 3-13 years, but cognitive development of children is different and follows a sequential pattern, as described by Piaget's theory of cognitive development. Children progress through four different stages of development, from the sensorimotor stage (0-2 years) to the formal operational stage (11-up). Therefore, a single UI model cannot be used for all ages, especially for pre-operational stage. In the field of Human-Computer Interaction (HCI) research, it is recommended that the UI design must be adjusted to the stage of children's cognitive development. The challenge ahead is to develop a UI design that can be adjusted to the cognitive development of children, to enable optimal child-robot interaction in education, with various roles of robots in education, such as tutors, peers, and tools. Various UI developments in CRI can be reviewed to adjust the UI according to the child's age or cognitive development, such as multimodal UI design which has the potential to develop UI for CRI in education, such as perceptual user interface or attentive user interface by applying various input modalities, such as detection of facial expressions, movements, objects, etc., so that the condition or behaviour of the child can be naturally detected without being limited to touchscreen UI input or tangible user interface [9].

Last but not least, and without claiming to be exhaustive, we would like to highlight the research of Taisuke Nagae and Jaeryoung Lee et al. They write that the advent of new technologies has led to the emergence of supportive robotics aimed at helping children with developmental disabilities achieve greater independence. Traditionally, research on robot therapy involved conducting experiments with the robot out of sight from the subjects. However, a new system has been developed that enables the robot to autonomously recognize the emotions of children with developmental disabilities and provide feedback. This system was designed to quantitatively measure emotional changes in children using skin conductance (EDA) during robot therapy. Results demonstrated that the NAO robot was able to recognize emotions on its own and provide feedback to the subjects. Additionally, a quantitative evaluation was conducted using EDA. By analysing symptoms associated with developmental disorders, there is potential to improve the recognition rate and customize therapy based on individual symptoms [10].

These studies highlight the importance of effective HRI. Drawing on a wide repertoire of literature on HRI, and gathering previous research and conclusions from it, we thought it worthwhile to carry out a SWOT analysis on the subject of effectiveness of human-robot interaction by NAO robot.

3 The Applied Method

SWOT analysis is a widely known strategic planning tool. It helps to understand and identify the application's strengths, weaknesses, opportunities and threats in a given situation. The analysis helps you to look at a given situation from both internal and external perspectives. The internal aspects are strengths and weaknesses, which we can usually influence directly. On the other hand, opportunities and threats, i.e., external factors, are often outside our control. In the following, we will attempt to map the use of the NAO robot as a tool for human-robot interaction through a SWOT analysis [11].

It is one of the most popular and useful methods for evaluating the goals of a project or application and helping to plan its development. The purpose of the analysis is to help you design a strategy that can realistically assess its potential and identify its strengths and weaknesses. This type of evaluation is also able to objectively see the specificities of the interfaces between the service, in our case the human and the NAO robot, and helps to identify the areas where you can get the most out of the use of the robot with the least risk.

In general, it is worth starting the analysis when the service is about to undergo a major transformation, when a new opportunity is emerging, when you want to introduce a new technological innovation or when the social environment has changed. A SWOT analysis is therefore a versatile method of analysis that may be worth repeating at any stage of a development. For NAO robot-related activities, these are the justifications

A ”SWOT” analysis is built up from a matrix of four elements. Each letter represents an internal or external area of the company to be examined:

- **S**trengths focus on the internal, positive attributes of an organization.
- **W**eaknesses identify processes and elements that can be improved.
- **O**pportunities summarize factors over which a firm has no control but can benefit.
- **T**hreats list the elements that can be barriers to success.

A SWOT analysis of using the NAO robot as a tool for human-robot interaction:

Strengths:

- NAO robot is highly interactive and can be programmed to perform a wide range of tasks and activities, making it a versatile tool for human-robot interaction.
- NAO robot is highly customizable and can be adapted to meet the needs of a variety of different users and applications.
- NAO robot is equipped with advanced sensors, such as cameras and microphones, which enable it to perceive and respond to its environment and users.
- NAO robot has a humanoid form, which can make it more approachable and engaging for some users than other types of robots.

Weaknesses:

- NAO robot is relatively expensive, which can limit its accessibility to some users and organizations.
- NAO robot has limited mobility and can only move on flat surfaces, which can limit its use in certain environments.
- NAO robot's battery life is relatively short, which can limit its use in longer interactions or activities.
- NAO robot is limited by its hardware capabilities, which may not be sufficient for more complex tasks or applications.

Opportunities:

- NAO robot can be used in a variety of settings, including education, healthcare, and entertainment, among others.
- NAO robot can be used to assist people with disabilities or special needs, such as autism or cerebral palsy.
- NAO robot can be used to collect data on human-robot interactions, which can be used to improve the design and development of future robots.
- NAO robot can be integrated with other technologies, such as virtual and augmented reality, to enhance the user experience.

Threats:

- NAO robot may face competition from other types of robots and technologies, such as virtual assistants and chatbots.
- NAO robot may face regulatory and ethical challenges related to privacy, security, and the potential for misuse.
- NAO robot may face social acceptance issues, as some people may feel uncomfortable interacting with robots or view them as a replacement for human interaction.

- NAO robot may face technical limitations and challenges related to software development, maintenance, and updates.

4 Human-Robot Interactions in Learning Processes

Technology has played an increasingly important role in education in recent years. One of the most significant developments is the integration of human-machine interaction into the learning process. HMI refers to the interaction between humans and machines, which can take many forms, including chatbots, virtual assistants, educational software, online forums and robots. By applying the elements listed in the SWOT analysis to the NAO robot-supported learning processes, we examined the role of NAO robot in learning processes [14].

One of the main advantages of HMI in the learning process is that it provides learners with access to a wealth of information and resources. Online forums and robots, for example, allow students to ask questions and get answers from experts and other students around the world. This can help deepen their understanding of complex topics and give them new perspectives on the material. In addition, educational software and/or robots can be tailored to the specific needs and learning style of each student, providing them with a personalized learning experience.

Another benefit of HRI in the learning process is that it can increase student engagement and motivation. Interactive software and games prgrammed in robot can make learning more fun and engaging, while chatbots and robots can provide immediate feedback and encouragement to learners. This can help keep students motivated and focused, leading to better learning outcomes.

However, HRI and also HMI has potential drawbacks in the learning process. One concern is that it can lead to a lack of human interaction and socialization. While online forums and chatbots can provide access to a global community of learners, students may miss out on the benefits of face-to-face interactions, such as building relationships with classmates and teachers. In addition, some students may have problems with the lack of personal attention and support they receive in a traditional classroom environment [13-15].

5 Results and Conclusions

Interpreting the strengths of the NAO robot, it can be programmed to do many different things and, thanks to its design, interact with people in many different ways. This makes it a flexible tool that people can use in many situations where

they need the help of a robot. To meet the specific needs of different users or applications, the NAO robot can be customized. This means that people can modify the robot's software or hardware to make it work better in a given situation. It is equipped with advanced sensors, such as cameras and microphones, that allow it to sense its environment and react to events around it. This helps it to be more responsive and interactive with humans. In terms of focusing on the role of human-robot interactions, the NAO's outstanding strength is that it has a human-like form, which can help some people feel more comfortable with it and engage more with it than with other types of robots. Because it has a familiar shape, people can more easily identify with it and understand what it is doing.

The SWOT analysis identifies not only strengths but also weaknesses. In our case, we can highlight the high cost of the robot, which means that it is not available to all users or organizations due to cost constraints. In addition, since it can only move on horizontal, flat terrain, the NAO robot has limited maneuverability, which makes it less useful in environments that are not flat or where it has to climb or navigate through obstacles. In terms of its hardware limitations, it is notable for its relatively short battery life, which may limit the amount of time it can be used in continuous interactions or activities before it needs to be recharged. These limitations and weaknesses may prevent it from performing more complex tasks or applications that require advanced capabilities beyond those provided by the robot.

The NAO robot is versatile and can be used in a variety of fields, including education, healthcare and entertainment. These possibilities mean or imply that the robot can assist in different applications and industries. It can help people with disabilities or special needs, such as people with autism or cerebral palsy. This means that the robot can provide additional support to individuals who need extra help with everyday activities. More generally, the NAO robot can collect data on how people interact with robots, which can be used to improve the design and development of future robots. This means that researchers can use the data collected from the NAO robot to improve the design and functionality of other robots. This can be done by integrating NAO with other technologies such as virtual and augmented reality to enhance the user experience. This means that the robot can be used with other technologies to provide a more engaging and immersive experience for users.

Interpreting the threat claims, it can be concluded that the NAO robot may face competition from other types of robots and technologies, such as virtual assistants and chatbots. This means that the robot will face challenges in terms of market competition and may need to differentiate itself from other similar technologies.

In other respects, the NAO robot may face regulatory and ethical challenges related to privacy, security and the potential for abuse. This means that regulatory and ethical considerations will need to be taken into account in the future to ensure the safe and responsible use of the robot. It may also be associated with

social acceptance problems, as some may feel uncomfortable interacting with robots or see them as a substitute for human interaction. This means that there may be resistance from some individuals or groups who are reluctant to accept robots as part of their daily lives.

From a technical perspective, the NAO robot may face technical limitations and challenges in terms of software development, maintenance and upgrades. This means that the robot may require ongoing technical support and updates to ensure that it continues to function properly and meet user needs. In addition, software development of the robot can be challenging and may require continuous investment in research and development (Figure 3).

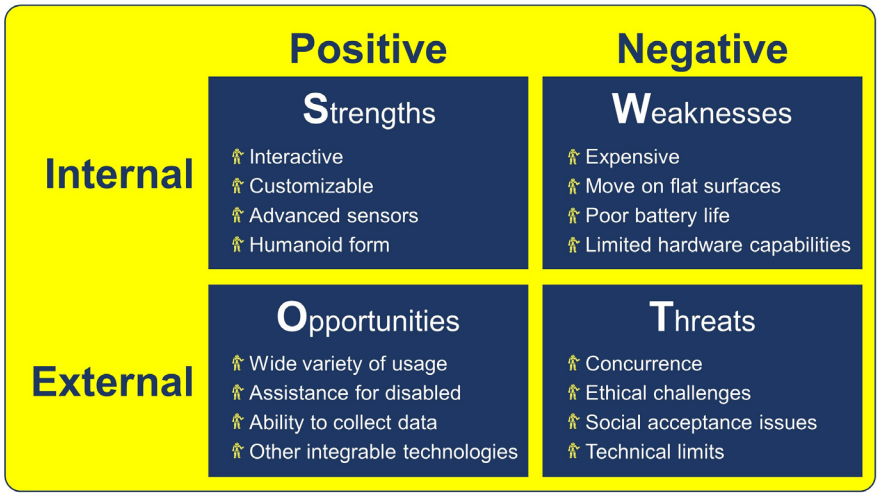

Figure 3
SWOT of effectiveness by NAO

6 Summary and Options for the Future

The NAO robot is designed to interact with humans in various contexts, including educational settings, research environments, and public spaces. The robot is equipped with sensors, cameras, and microphones that enable it to perceive and respond to human actions and speech.

Several studies have examined the human-robot interaction aspect of the NAO robot, and the findings suggest that the robot is effective in engaging with humans and eliciting social responses [12].

For example, a study conducted in a primary school in Italy found that the NAO robot was able to elicit social and emotional responses from young students, such as laughter, smiles, and positive facial expressions. Similarly, a study conducted in a retirement home in the Netherlands found that the NAO robot was able to engage with elderly residents and stimulate social interactions, which in turn led to improved well-being.

However, the human-robot interaction aspect of the NAO robot is not without challenges. For example, some studies have found that the robot's speech recognition and natural language processing capabilities can be limited, which can affect the quality of interactions with humans [16][17].

Overall, the human-robot interaction aspect of the NAO robot has shown promise in enhancing social interactions and well-being in various contexts, but further research is needed to address the challenges and improve the robot's capabilities in this area [18][19].

In summary, HRI has the potential to revolutionize the learning process by providing students with access to a wealth of information and resources, increasing engagement and motivation, and providing a personalized learning experience. Potential disadvantages of HRI, including the lack of human interaction [20-22] and socialization, as well as the costs of implementing and maintaining these tools, must be considered. Ultimately, the key to successful HRI-based learning is finding the right balance between technology and people.

The importance of human-robot interfaces will become increasingly important in the world of work and education as a result of digitalization processes. The efficiency of the human-robot interface can be further developed in the present and in the future on the basis of artificial intelligence, for which the technical conditions are already in place. Learning, then self-learning, and finally AI-based robots will help to set future trends, the exploitation of which for educational purposes will also become increasingly important. This is particularly true in education in STEM fields [23-25] Some researchers have already begun studies in which humanoid robots are used to help students learn healthy lifestyles and basic skills. [26-27].

As a continuation of the empirical research work that has been started, future experiments will also explore and analyze the limitations of the NAO robot and the current shortcomings of the technology.

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