BEN-GURION UNIVERSITY OF THE NEGEV

FACULTY OF ENGINEERING SCIENCES

DEPARTMENT OF INDUSTRIAL ENGINEERING AND MANAGEMENT

Development of polite robots and evaluation in real world scenarios

THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE

M.Sc. DEGREE

By: Eliran Itzhak

March 2022

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Supervised by: Prof. Yael Edan and Prof. Noam Tractinsky

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Abstract

Robots are increasingly entering into everyday life tasks serving as housekeepers, caregivers, and tutors. As such they must communicate and interact with non expert users and bystanders. This calls for designers of these social robots to keep in mind various interaction aspects, including the extent to which cultural norms and social norms should be followed; the way a robot needs to interact with humans.

This thesis examined one aspect of Human Robot Interaction (HRI), focusing on polite robots in real-life scenarios. We focused on developing and evaluating polite behaviours for robots performing daily life tasks. The goal is for the robot to perform collaborative tasks while taking into account their expectations and preferences.

The attitude of a robot is an essential feature for creating socially interactive robots. A successful interaction is a challenging task. To achieve this, robots must be able to communicate naturally with humans. Studies on this matter are aimed at enhancing human robot interaction. In this thesis, we examined the influence of polite behaviours based on Lakoff’s theory of politeness, in real-life scenarios for different aspects that influence user's perceptions. We developed polite behaviours for non-humanoid social robots, developed several experimental systems and evaluated the users’ perception in a series of user studies. User studies were conducted with both old adults and young adults populations.

The first part of the research examined polite behaviours for robots performing table-setting tasks. For these experiments, a mobile robotic system (Turtlebot3 Burger) was developed, the function of which was to carry from one place where meal utensils were placed approximately to the participant. Another system was developed in a parallel study that incorporated a robotic arm (KUKA) which set the meal utensils near the participant. Both of these systems used a Graphical User Interface (GUI) through which non-verbal communication was performed. The polite behaviors were composed based on Lakoff’s three rules of politeness. In each scenario a different level of politeness was activated and the robot behaved accordingly. The results showed that the high level of politeness was the favorite among the participants. Results from the study demonstrated that participants were able to perceive the difference between the three different polite levels in terms of enjoyment, satisfaction and trust. The participants preferred the polite behaving robots.

The second part of the research continued to examine the polite robotic system but extended it to real world scenarios. We investigated the influence of politeness and of erroneous robot behavior on users' perceptions in a series of user studies with different robots and populations. The experiment focused on a human robot collaborative task to complete a common goal. A robotic mobile system (Turtlebot3 Waffle) was developed in which participants must remotely move a mobile robot between three different rooms. The goal was to put together a word consisting of three unknown letters that are scattered in a defined environment. Another system developed in a parallel study incorporated a robotic arm (Dobot) in which a collaborative cube arranging task was developed. The participants were asked to arrange six different colored cubes according to instructions. Results revealed that among all experimental groups the most preferred scenario was the Polite-Correct behaving robot. Furthermore, Polite-Correct behavior was preferred in both experiments by both young and old participants as evident from all three dependent variables while Polite-Erroneous got less sympathy.

The main contribution of this work is the finding that people can distinguish degrees of politeness in the behavior of non-humanoid social robots designed based on Lakoff's politeness rules. However, although politeness is generally a welcomed robotic quality, it cannot make up for robotic errors. Moreover, when the robot errs, its politeness may even annoy the user. This conclusion should be further studied among additional population groups, using a variety of robots and comparing influence in case of different task objectives and different types of errors (e.g., low vs. high error costs).

Keywords: Human Robot Interaction (HRI), Politeness, Older adults, Social assistive robot, Assistive robot, Robot errors.

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- **E. Itzhak***, S. Kumar*, Y. Edan, G. Nimrod, V. Sarne-Fleischmann, N. Tractinsky. Politeness cannot make up for errors. Young and old people experiencing collaboration with robots. Submitted March 2022. IEEE Trans. HMS.

Submitted reviewed conference publication

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*authors had equal contribution

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Chapter 1. Introduction

1.1 Overview

Robots are increasingly entering into everyday life tasks serving as housekeepers, caregivers, and tutors. As such they must communicate and interact with non expert users and bystanders.

Assistive robots are robots that are designed to perform tasks normally done by humans in an environment in which humans work as well (van Osch et al., 2014). However, they are not required to accomplish these tasks in the same way as humans do and do not need to look like a human being (van Osch et al., 2014). Social robots are designed to naturally interact with people in different applications such as entertainment, education, healthcare, quality of life, and tasks that require teamwork (Conti et al., 2020; Čaić et al., 2019; Shishehgar, 2019).

A socially assistive robot (SAR) blends the functions and characteristics of both assistive and social robots (Pfeil-Seifer & Mataric, 2005), helping humans (as assistive robots) through social intelligence (as social robots). A social assistive robot differs from a social robot and a robot for entertainment whose job is to provide simple interaction. In contrast, a social assistance robot is required to support the users' daily activities (Pu, 2019). Designing such a robot raises many challenges due to the many requirements that must be considered, depending on the person using the robot. The long-term goal of developing social robots that will serve as partners for humans is quite challenging. To do this, robots must be able to communicate naturally with humans both verbally and nonverbally (Breazeal et al., 2016). Examples of social robot applications include conversational robots (Sabelli et al., 2011), companionship robots (Breazeal & Scassellati, 2000), pets (Wada & Shibata, 2007), therapeutic aids (Dautenhahn, 2003), and toys (Fong et al., 2015).

A special focus of social robots is towards the elderly population. The elderly population is expected to undergo a very significant demographic change in the coming decades. Current forecasts show that this population will double by 2050 and triple by 2100 (United Nations, 2017). This can cause financial difficulties when it comes to the health and quality of life of the elderly. Since the caregiver population does not increase at a similar rate, there is an increasing need to develop solutions to assist the older adults. A possible technological solution is the use of robots to assist the older adults (Stone, 2021). In order to keep the elderly population in their natural environment as much and as long as possible it seems that robots may contribute significantly (Beer et al., 2012).

Social assistive robots have been developed for older adults for a wide range of applications (Tang et al., 2015). These are robots who are skilled in completing a complex series of physical tasks and include a social interface to ensure efficient and natural collaboration (Zafrani & Nimrod 2019). Social robots can be classified into (Broekans et al., 2009; Abdi et al., 2018) service type robots (denoted also as assistive robots) - designed to assist in activities of daily life and companion type robots - usually related to the improvement of the psychological state and general well-being of its users (denoted also as social robots) providing the older adults with entertainment in friendly and enjoyable interaction (e.g., access to games, music) along with personal assistance (e.g., managing calendar).

Assistive robots have been developed to assist older adult in three types of activities: Activities of Daily living (ADLs), Instrumental Activities of Daily Living (IADLs) and Enhanced Activities of Daily Living (EADLs). ADLs are basic self-maintenance tasks e.g., bathing (Zlatintsi et al., 2020), dressing (Zhang et al., 2019); IADLs are useful tasks that are not mandatory for basic functioning, but essential for an independent life to interact with the environment such as household chores (Pinacho et al., 2019), shopping (Niemelä et al., 2018). EADLs are activities that make it easier to participate in social and enriching activities such as leisure and learning new skills (McColl et al., 2013; Smarr et al., 2014; Mitzner et al., 2014); these are also denoted as social robots.

All robot types have great potential to promote autonomy and quality of life among older adults (Zafrani & Nimrod, 2019). However, to achieve acceptable robotic technologies, an in-depth understanding of what makes interaction between robots and older adults successful is necessary (Zafrani & Nimrod, 2019). In our research we focused on one interaction aspect of assistive robots in an IADL task, addressing the incorporation of politeness in the robots (study 1). We also addressed social robots' interaction as related to politeness in real world scenarios (study 2). We conducted a series of user studies with both older adults and young adults.

1.2. Background and problem description

1.2.1. Politeness

Definition - Politeness is one of the main social constraints in human interaction that regulates participants' media consideration of the feelings of others. It is generally considered as an expression of human culture, and it is one of the most effective strategies that regulate interpersonal relationships in human communication. (Yu & Ren, 2013).

Lakoff's approach to politeness (Lakoff, 1973) has two main components: clarity and politeness. The first component is the "was clear" rule. When conveying a message, a person we intend to convey the message should do so in a clear manner that is not ambiguous. The second component is the "Be Polite" rule. This rule consists of a set of three principles: (i) "Do not Impose" - means not to infiltrate "other people's business". One should know how to keep a distance and not enter another's area without permission. We need to keep our distance from the other side (how close our relationship is with the person we are talking to). (ii) "Give options" - states that we allow the other party options to refuse or accept our requests and desires. Linguistically it is characterized by saying things hesitantly, leaving the possibility of decision to the other side. (iii) "Be friendly" - emphasizes equality and closeness between the speaker and the listener. The rule suggests that informal expression conveys feelings of solidarity that make the recipient feel wanted.

Brown and Levinson (1987) defined "face" as the central thing in politeness. They described two aspects, identified as a negative face and a positive face. Negative faces can be defined as the basic claim of an expression of personal freedom of action and personal space, which others will not invade. Positive faces represent the desire to create a positive self-image in relation to society. This means that a person seeks to be perceived as positive by society and get their approval. The approach to the negative and positive face on the part of the person creates norms and rules that guide the way society communicates. However, a face is also a basic desire that every person wants to satisfy, i.e., the desire to maintain a negative and positive face in direct interaction with others.

Leech's (1983) principle of politeness provides a pragmatic model that explains how it is intended to provide a description — why consequences (i.e., implied meanings) arise. Leech's theory states that the less painful and conducive a particular statement is to the person listening, the more polite it becomes. The theory describes the polite value of a statement using a "cost-benefit scale", i.e., a scale that represents the cost-benefit value of actions. These scales of benefit are limited by maximum courtesy.

To apply politeness to software, it must be defined in terms of information (Whitworth 2005). Bar-Or and Tractinsky (2017), examined the application of Lakoff politeness theory in the field of human-computer interaction. Their research paper offers an approach based on a scientific theory about politeness in human-computer interaction and also provides empirical evidence supporting this approach.

1.2.2. Polite Robots

Robots that interact politely with users involve several considerations. To ensure efficient collaboration it is important to ensure that the robots are equipped with high-quality human-robot interaction (HRI) skills (Loi et al. 2018). It is possible to design the interaction with the robots to express social characteristics related to humans. This may help to achieve transparency so that the action of a system, or intention of action, is clear (Inbar & Meyer, 2019). This behavior can facilitate communication in human interaction and minimize the potential for conflict and confrontation (Salem et al., 2013). Politeness in the field of HRI has been explored in several studies (e.g., healthcare service (Lee et al., 2017), adaptive expressive robot (Ritschel et al., 2019) and in animation (gatekeeping robot, Inbar and Meyer 2019) based on Brown and Levinson's politeness theory (Brown et al. 1987).

A previous study (Kumar et al., 2021) that examined incorporation of politeness in a robotic system that consisted of a manipulator in a table-setting task showed that the quality of interaction was influenced by politeness - participants significantly preferred the polite state of the robot. This thesis aimed to expand on this research and developed and evaluated the effect of politeness in interaction with different types of robots and users. To ensure thorough evaluation we developed the systems for several real-world scenarios. Reliability is a key parameter to successful implementation of robots in human environments (De Santis et al., 2008). However, robots performing in real world scenarios tend to err or fail (Honig & Oron-Gilad, 2018). The robots performing the tasks correctly is therefore important (De Santis et al., 2008).

1.2.3. Correct and Erroneous Robot Behaviors

As artificial and robotic intelligence systems become more complex and autonomous, and make decisions for themselves, users become less aware of their intent and internal processes (Nesset 2021). Social robots are not yet in a technical state where they operate without errors (Mirnig et al., 2017). Although considerable effort has been put into making robots more reliable, experience shows that robots are often challenged by frequent failures (Honig & Oron-Gilad 2018). One aspect of the field of human-human interaction (HHI) is that imperfections make human social actors more likable and reliable and their attractiveness is increasing (Mirning et al., 2017). A social norm violation (SNV) means that the robot's actions deviate from the basic social norm, that is, the known interaction steps that a particular situation is likely to take and a technical failure (TF) means the robot experiences a technical disruption that is perceived as such by the user (Miring et al., 2015).

The robot's errors have a significant impact over time on participants' future beliefs about the robot, which creates a diminution in trust in their assessments of the robot's reliability. (Wright et al., 2019). The way a robot operates in failure affects the willingness to use the robot again (Lee et al., 2010), affects task performance, influences the trust that the user gives in the robot, and how users perceive the robot (Honig & Oron-Gilad, 2018).

There have been numerous studies evaluating the effect of erroneous robot behavior on the user (e.g., Mirnig et al., 2017; Ragni et al., 2016; Salem et al., 2015; Salem et al., 2013; Kahn et al., 2012; Lee et al., 2010). The process of reporting errors causes increased likeability and anthropomorphism despite a reduced task performance (Salem et al., 2013). In another study with a non-task related error, the faulty robot was perceived as more likable by the participants and the users did not perceive the robot as less intelligent (Mirnig et al., 2017). In Kahn et al., (2012), participants who interacted with a humanoid robot that incorrectly assessed their performance perceived the robot as having emotional and social attributes. However, a service robot that made an error had a strong negative impact on people's ratings of the service quality (Lee et al., 2010) and made robots seem less human (Salem et al., 2015).

1.2.4 Parameters in HRI evaluation

When evaluating human-robot interaction it is important to consider several aspects related to both the human and robot parameters (De Graaf & Allouch, 2013), and the task and the environment (Olatunji et al., 2020, 2021; Honig et al., 2018).

Both population-relevant and individual aspects (Tapus et al., 2007) should be considered in HRI. The special needs of each user are important (Tapus et al., 2007) and hence should be evaluated in the field of human-robot interaction (Burema 2021). The age for example has impact on behavior and willingness to use technology (Kuo, 2009). Furthermore, there are differences in HRI between age groups (e.g., Feingold-Polak et al., 2018; Wagner-Hartl et al., 2020; Kuo et al., 2009). During this study we *examined the effect of age on participants' perceptions focusing on two populations, old and young adults*.

Additionally, individual and cultural differences such as gender are important considerations in robotics design to influence the interaction between robots and humans (Nomura 2017; Kuo et al., 2009). Gender affects how users respond to a robot (Forlizzi 2007) this might be caused by the differences between male and female interacting with the robot (De Graaf & Allouch, 2013; Wagner-Hartl et al., 2020) and between negative attitudes and behaviors towards robots (Nomura, 2006). Various studies (Ritschel et al., 2019; Krakovski et al., 2021; Nomura & Takagi, 2011; Siegel et al., 2009; Eyssel et al., 2012; Heerink 2011; Wang et al., 2020) have suggested that gender does influence perceptions of the robot. Yet, some studies pointed out that gender does not have an important role in the perceptions of the robot (Inbar & Meyer, 2019). Of the studies cited in this paragraph, some were tested for humanoid robots (Nomura 2017; De Graaf & Allouch, 2013; Nomura, 2006; Krakovski et al., 2021; Nomura & Takagi, 2011; Siegel et al., 2009; Eyssel et al., 2012; Heerink 2011; Wang et al., 2020; Inbar & Meyer, 2019) and some for non-humanoid robots (Kuo et al., 2009; Forlizzi 2007; Ritschel et al., 2019) with no conclusion. In this study we evaluated if gender *influenced interaction*.

Third, socially interactive robots can have different forms and functions (Fong et al., 2003). HRI taxonomy takes into account three categories: interaction (e.g., field of application, type of interaction), robot (e.g., robot task, morphology), and team classification (e.g., role of each agent, team composition, Onnasch & Roesler, 2021). Previous studies have mainly focused on comparing different anthropomorphic type robots (Fong et al., 2003; Goetz et al 2003). However, since the type of robot and the task affect the interaction (Olatunji et al., 2021) it is important to consider take both in the evaluation. Therefore, in order to identify commonalities in polite robots design across test cases we evaluated several systems and investigated the influence of age, the tasks and robots on these designs. Hence, we evaluated if *type of robots influenced interaction*.

Previous studies (Woods et al., 2006) suggested that video experiments could be used for exploratory studies in HRI and that both direct and extended interaction could provide sufficient experience (Gou et al., 2021). However, direct contact (live experiment) was found to affect both explicit and implicit attitudes, while extended contact (video experiment) affected mostly implicit attitudes (Woods et al., 2006). In this study we *compared a live experiment to a video experiment*.

1.3 Research objectives

The objective of this research was to develop politeness for robotic systems and evaluate the influence of politeness in human robot interaction in real world scenarios. The real-world scenarios took into account that robots can err. Two experimental systems were designed and developed for two different tasks and four different robots. The specific research focused on implementation of politeness in several non-humanoid robotic systems and evaluation of its influence on human robot interaction in a series of user studies. This included:

1. A multi-experiment study with non-humanoid robots involving different mediums of interaction.
2. Tasks that included correct and erroneous robot behaviors.

In this thesis we developed politeness for two tasks of a mobile robot. In a parallel study, politeness was developed for two tasks of a robot manipulator. We ran experiments with different age groups and analyzed the results.

1.4. Thesis structure

The overall research methodology is described in Chapter 2. Description of the system developed for the studies is presented in Chapter 3. The study includes two separate experimental parts that evaluate the effect of politeness (Chapter 4) and correctness of robots' behavior (Chapter 5) on human-robot interaction. Each chapter includes a focused literature review detailing the methods of experiment and analysis and results. Overall conclusions and future research are discussed in Chapter 6.

Chapter 2. Methodology

2.1. Overview

This research aimed to develop and evaluate the effect of robot's polite behavior on users in real life scenarios. To ensure a thorough study, different influencing parameters were evaluated (age group, type of robot/task). The research consisted of two main studies, involving four experiments performed with four different robots platforms examining politeness in two types of tasks:

1 *Table setting task*. The robot performed an assistive task in which it set the table for participants with a manipulator arm robot (KUKA) and mobile robot (Turtlebot burger) that carried utensils for the participants.

2 *Game task.* participant and robot performed together a task. A Cube game where the participants needed to build a color cube tower while a manipulator robotic arm (Dobot) brings it to them each time. A Maze game – where participants needed to find a specific hidden word in different rooms while a mobile robot (Turtlebot Waffle) robot navigates between the rooms. In both game tasks the participants had to complete the task in a certain order predefined for the user (according to the color of the cube/ room). That is, the colors were the way to effectively complete the task.

We developed politeness for the robots in each of the tasks based on Lakoff theory of politeness. The experiments examined whether there were differences between the different levels of politeness and the subject's preference for the level of politeness at which they would have preferred to perform the task. We further developed and tested the polite behaviour in a real-world scenario which means we included robot making errors. This was examined using a model considering different variables as described in the next section.

2.2 Model description

We examined which independent variables influence the user's perception on the interaction with the robot (Figure 1). The variables considered:

Levels of politeness: Based on Lakoff's theory of politeness, three different levels of robot politeness in human-robot interaction were developed for a table setting task and implemented with two different types of robots (a robotic manipulator and a mobile robot) as follows:

- ***Three politeness rules.*** all three rules ("don't impose," "give options," "be friendly") were applied.
- ***One politeness rule.*** only the "don't impose" rule was applied.
- ***No politeness rules.*** none of the framework's rules was applied, although the robot did not explicitly or ostentatiously violate them.

Robot's behaviours: In the game tasks the user operated the robots in the following four scenarios which combined the robot's politeness (polite / no-polite) and its operation (correct / erroneous).

Politeness was defined based on Lakoff's theory and included 3 sub-rules: Do not impose, Give options and Be friendly. Only two levels of politeness were used in these experiments: 'Polite' – all rules were applied and 'No Polite' – none of the rules were applied. The experiments included four behaviours:

- ***No-polite erroneous (NPE).*** The robot performed the task, but not in the required order for the arrangement. The robot did not exhibit any of the polite behavior rules.
- ***No-polite correct (NPC).*** The robot operated according to the colored items in an order that would be easy for the user to execute the task. but did not exhibit any of the polite behavior rules.
- ***Polite erroneous (PE).*** All three rules ("do not impose", "give options", "be friendly") were applied. However, in this condition, the robot made a mistake in performing the task.
- ***Polite correct (PC).*** All three rules ("do not impose", "give options", "be friendly") were applied.

Type of condition: The Covid-19 pandemic posed serious limitations on our ability to conduct ordinary HRI research. Therefore, in study 1 we examined the system also using videos that illustrated the behavior of the system and each participant watched the different scenarios. After social distance guidelines were eased, live experiments were performed. This provides us with insights of how people perceive the interaction in two types of conditions – in video and in real life, this step can also give a distinction to the design and improvement of the system according to participants' opinions prior to full system development

Robot type: Each study included two types of robots: a manipulator, that served to bring the items closer to the user during the interaction and a mobile robot that automatically navigates the space according to the scenario.

Age group: The experimental population was composed of adults and young adults so we took into account the influence of age. Additionally, gender preferences were evaluated.

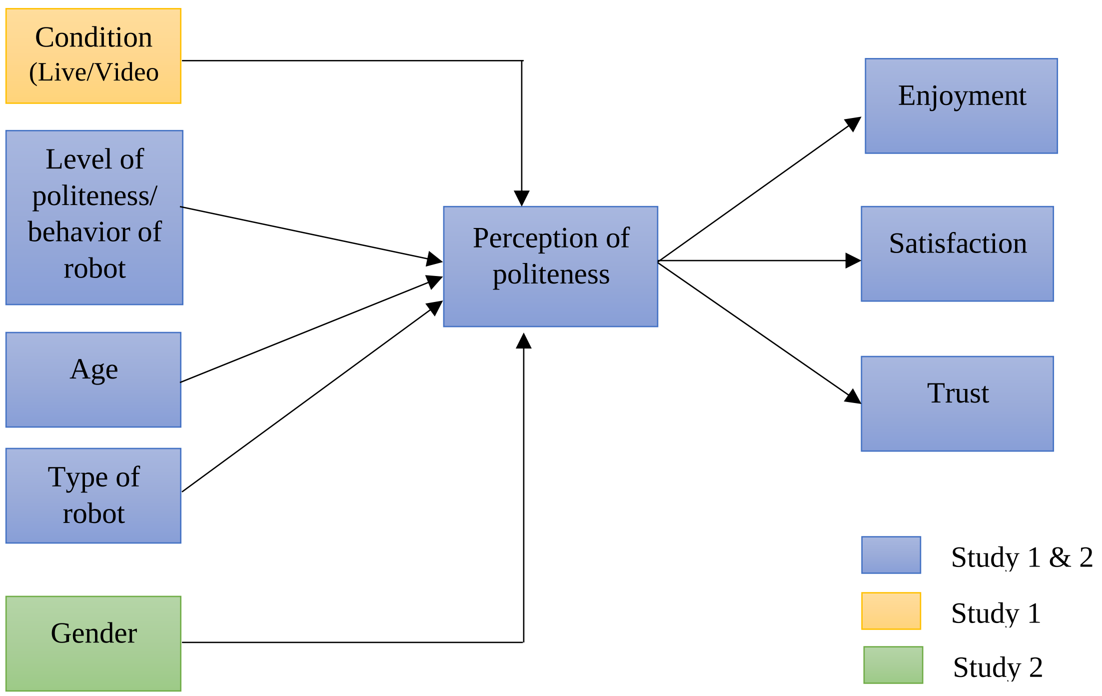

Figure 1. Research model and related experiments.

2.3. Study 1: Study case: influence of politeness in human robot interaction

Acceptance of any technology in a society is highly dependent on functional and social aspects (Fridin & Belokopytov 2014). Accordingly, the social behavior of robots is considered influential on humans' willingness to interact with them (Kerstin 2007).

This study focuses on developing politeness levels for human-robot collaborative tasks based on a sociolinguistic politeness theory. Further, we evaluated the influence of politeness in several user studies both by a video and live experiment with both old adults and young adults. In a previous experiment, we performed a preliminary investigation with old adults and young adults with a manipulator robot (Kumar et al., 2021). In the current research, we compare these experiments to a new video experiment with the same task and robot and to new experiments performed with a different type of robot (a mobile robot) in both video and live experiments. Both robots in these studies were non-humanoid.

The main contribution of this work is the finding that people can distinguish degrees of politeness in the behavior of non-humanoid social robots designed based on Lakoff's politeness rules. In general, the results suggest that both older and younger adults perceive politeness differences in the behavior of social robots, although there were some mild differences in proportions. Furthermore, both populations preferred robots that were designed with the three politeness rules over robots that were not designed with any of the politeness rules. The main aspects of this study are summarized in Table 1.

2.4. Study 2: Polite behavior with correct erroneous behaviors

This study aimed to examine the effect of politeness on the human-robot interaction with two different tasks implemented with two types of robots. To incorporate real-world scenarios, erroneous committed by the robot have also been introduced and we evaluated its influence. Based on results of study 1, we formulated only two different levels of politeness –no-polite and polite behaviors. In the polite behavior condition, all three sub-rules were employed. In the no-polite condition, Lakoff sub-rules are not implemented. This study also addresses the effect of erroneous made by the robot on the overall HRI performance comparing polite and no-polite robots. The main aspects of Study 2 are summarized in Table 1.

Independent variable	**Study 1** Table setting task	**Study 2** Game task
Robot behaviors	No rules polite level One rule polite level Three rules polite level	No-polite Erroneous No-polite Correct Polite Erroneous Polite Correct
Robot platforms	Kuka + Turtlebot3 burger	Dobot + Turtlebot3 Waffle pi
Task	Table setting	Cube and Maze games
Population	Older adults and students	
Thesis chapter	Chapter 4	Chapter 5

Table 1. Main aspects of Studies 1 and 2.

Chapter 3. System development

3.1 Overview

Two types of robotic systems were developed with different robotic platforms and tasks. Mobile robots - their main action was to automatically navigate space from point to point according to the experimental scenarios. Manipulator robots which were applied in tasks that aimed to make objects accessible to the user. The mobile robotic systems were developed as part of this thesis; the manipulator robotic systems were developed as part of a parallel research but were used to compare the influence of the robotic system on the user perception of polite robot behaviors.

3.1. Table setting task (Turtlebot3 Burger)

A small mobile robot (Turtlebot3 Burger with two motorized wheels and a LIDAR used for navigation) was used for the table setting task – the robot was designed and programmed to bring dishes and cutlery for the table setting task (Study 1). To bring the utensils, a wooden structure with a tray on top of it was mounted on the robot (Figure 2). The height of the wooden frame was 42 cm, and the diameter of the tray was 29 cm.

Figure 2. Photograph of table mobile setting robotic system structure.

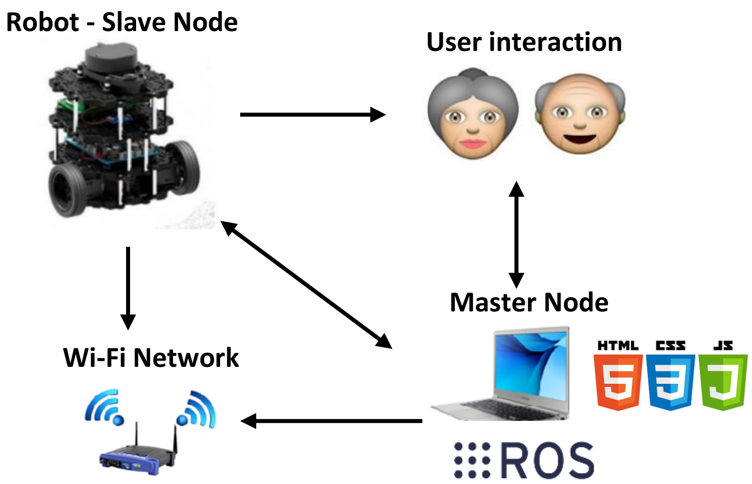

Figure 3. Schematic system design of the table setting task with the Turtlebot3 burger

Each participant interacted with the robot via Graphical User Interface (GUI). The interface was developed in HTML and JavaScript. The Robotic Operating System (ROS) used for TCP/IP protocol was developed for communication between the GUI and the robot with connecting the same Wi-Fi network (Figure 3). The mobile robot performs the tasks by bringing items to the participants according to the scenarios.

The software code is documented in Appendix A.

3.2. Maze task (Turtlebot3 Waffle pi)

TurtleBot3 Waffle Pi robot, an extended version of the Burger with a high payload and additional sensors was developed for the maze task in Study 2. It is 141 mm high, 306 mm with maximum payload 30 kgf and angular velocity 1.82 rads/s. The robot has a Raspberry Pi Camera installed that transmits on the GUI screen the environment in which it is located. The interface was developed in HTML and JavaScript and communicate using TCP/IP protocol between the interface and the robot (Figure 4). The robot moved around automatically but allowed the participant to turn the robot around (angular displacement) to scan the environment when stopped (Figure 5).

The software code is documented in Appendix B.

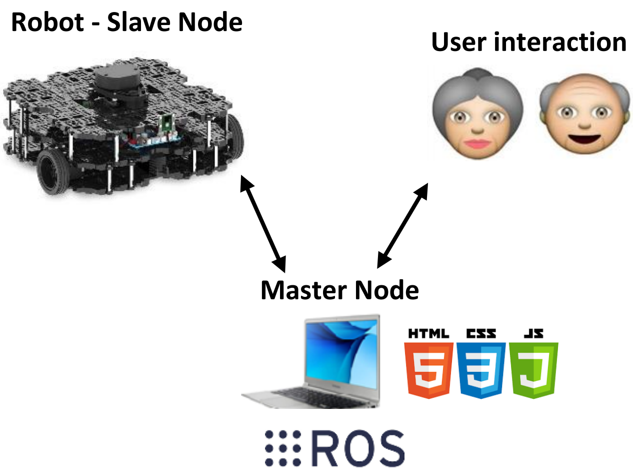

Figure 4. Schematic system design of the Turtlebot3 Waffle.

Figure 5. Photograph of maze robotic system.

3.3. Additional systems used

3.3.1. KUKA

A table setting task was designed with a KUKA LBR IIWA 14 R820 (7 degrees of freedom) manipulator for study 1 (Figure 6). Additional components such as a gripper and suction pipe were built and connected to the system. Another component that was connected to the system is the computer screen, through which the robot communicated with the participants. A TCP/IP protocol was developed for communication between the GUI and the robot (Figure 7). The participant had to interact with the GUI and the robot offered two options for setting the meal - either a meat meal or a dairy meal.

The software code is documented in Appendix C.

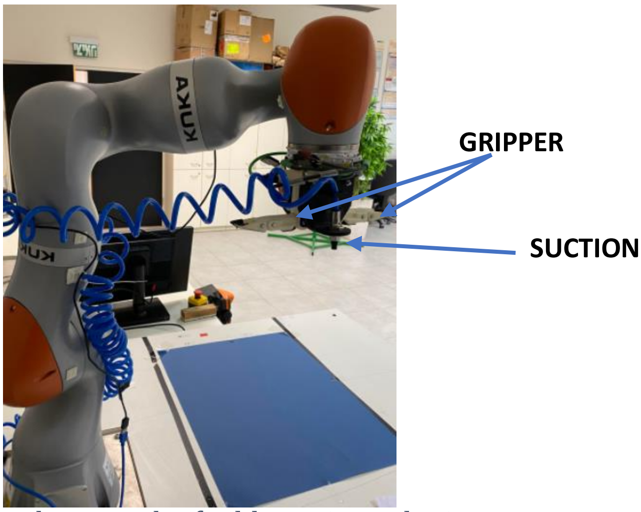

Figure 6. Photograph of table setting robotic system structure.

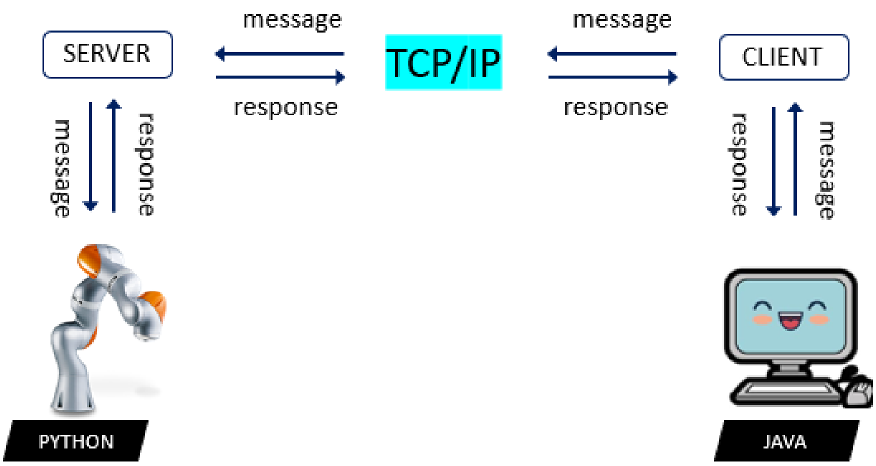

Figure 7. Schematic system design KUKA.

3.3.2. Dobot

A four degree of freedom DOBOT Magician was used for the cube game task in Study 2. It is 135 mm high, 158 mm wide and has a 320 mm radius with a payload of 500 g. It connects to the computer through a USB connection and was equipped with a suction gripper to pick up the cubes. This robotic arm was programmed using the Python programming language. The participant communicates with the robot through a user interface implemented on a GUI screen (Figure 8).

The software code is documented in Appendix D.

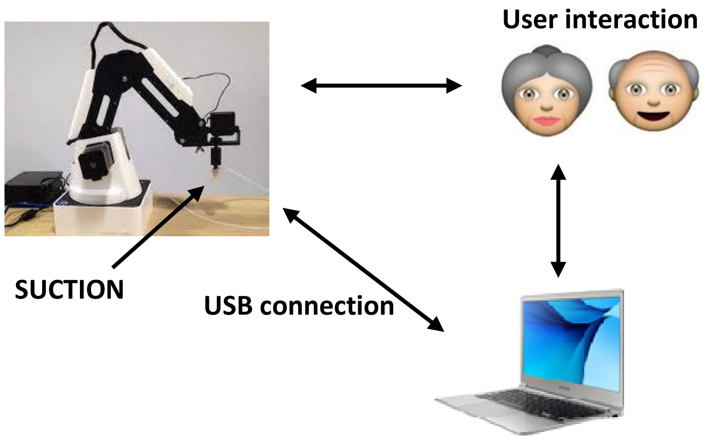

Figure 8. Schematic system design cube task with Dobot.

Chapter 4. Politeness in human-robot interaction: A multi-experiment study with non-humanoid robots

Politeness in human-robot interaction: A multi-experiment study with non-humanoid robots

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Abstract: We studied politeness in human-robot interaction based on Lakoff's politeness theory. In a series of eight studies, we manipulated three different levels of politeness of non-humanoid robots and evaluated their effects. A table-setting task was developed for two different types of robots (a robotic manipulator and a mobile robot). The studies included two different populations (old and young adults) and were conducted in two conditions (video and live). Results revealed that polite robot behavior positively affected users' perceptions of the interaction with the robots and that participants were able to differentiate between the designed politeness levels. Participants reported higher levels of enjoyment, satisfaction, and trust when they interacted with the politest behavior of the robot. A smaller number of young adults trusted the politest behavior of the robot compared to old adults. Enjoyment and trust of the interaction with the robot were higher when study participants were subjected to the live condition compared to video and participants were more satisfied when they interacted with a mobile robot compared to a manipulator.

Keywords: Politeness, Human Robot Interaction, Older adults, Social assistive robot, Assistive robot**.**

1. Introduction

Acceptance of any technology in a society is highly dependent on functional and social aspects [1]. Accordingly, the social behavior of robots is considered influential on humans' willingness to interact with them [2]. Here we consider one aspect of such behavior – politeness. Politeness has an important role in human social behavior, helping humans increase interaction amongst themselves and avoid conflict. According to Lakoff [3], politeness is "*a system of interpersonal relations designed to facilitate interaction by minimizing the potential for conflict and confrontation inherent in all human interchange*." The leap from politeness as a key construct in human-human behavior to its role in human-technology communication may not seem straightforward. Yet, in the field of human-computer interaction (HCI) media equation theory suggests that humans treat machines similar to other humans [4]. It was suggested that the etiquettes of a computer were an important factor while interacting with humans [5]. Developing etiquettes could influence humans' trust in automation as it would help them understand the way automation works [6]. Trust is the ability of the trustee to perform a significant action based on the expectation of the trustor which the trustor could rely upon [5][6]. Accordingly, it could help bridge the gap between humans' expectations and the agent's functionality [6]. Further empirical research has shown that people tend to be polite towards the computer after a conversation has been initiated [9]. Consequently, research has also argued for the study of politeness in HRI [10][11][12]. Subsequent empirical research on the topic has focused mainly on tasks with humanoid robots, e.g. [13] [14] [15] [16] [17] [18]. No study, thus far, explored politeness in non-humanoid robots according to our knowledge.

This study focuses on studying the effects of social robots politeness in human-robot collaborative tasks. For this purpose, we have adapted a sociolinguistic approach to politeness in general [3] and particularly in the field of HCI [22]. We elaborate on this approach in Section 2.1. We have developed three different levels of robot politeness based on the politeness rules outlined by [3]. The politeness rules have been incorporated in a human-robot task with different non-humanoid robot types (mobile and manipulator robots). Further, we evaluated the influence of politeness in several user studies both by a video and live experiment with both old adults and young adults. In a previous experiment, we performed a preliminary investigation with old adults and young adults with a manipulator robot [19]. In the current paper, we compare these experiments to a new video experiment with the same task and robot and to new experiments performed with a different type of robot (a mobile robot) in both video and live experiments. Thus, we were able to study the effect of the three politeness rules on the user's perceptions (enjoyment, trust, satisfaction) according to age, type of robot or task, and study condition (live or video).

The next section discusses approaches to the study of politeness, emphasizing Lakoff's approach to the concept and its relevance to non-humanoid robots. This section also reviews related work on the effects of age, type of robot/task and study condition in HRI studies, explaining the rationale for the current study. This is followed by methodology (section 3), analysis and results (section 4) and discussion (sections 5 and 6), and conclusion (section 6) sections.

2. Theoretical Background and Related Work

2.1 Politeness

Most previous research on politeness in HRI has adopted Brown and Levinson's [20] theory of politeness, which centers on the concept of "face." The gist of the theory is the protection of 'face' or image by the social actors in a public domain. According to this theory [20], there are four strategies that a person could take to mitigate the "face-threatening" acts. The person can mitigate the situation by using an on or off-record strategy (on-record includes bald, positive and negative strategies; off-record strategy is to be indirect, using irony or metaphor). An actor can go on-record either without a redressive action (actions which are taken to minimize or overcome the intention of face-threatening) termed as bald strategy (being direct and clear in its strategy) or with a redressive action which includes two different strategies, namely positive and negative. In positive strategy, the face-threatening act is minimized by agreeing, being friendly, being optimistic etc. whereas in negative strategy, the face-threatening act is minimized by avoiding conflicts in showing consideration. Based on this theory, a humanoid mobile robot was used to remind a user about medication while the user was busy with a primary task [17]. The study involved four types of polite strategies i.e., bald, positive, negative, and a mixed strategy (combination of positive and negative). Results revealed that negative and a mixture of positive and negative strategies were recommended for polite behaviors. The positive strategy in Brown-Levinson theory was discouraged. A series of study, which includes showing static pictures and animated clips to the participants, with a gatekeeper (peacekeeper) robot interacting with a human revealed that a polite strategy influenced the interaction [16]. The participants noted that the robot with the polite behavior was friendlier, fairer, and acted appropriately. It also revealed that the polite robot was less threatening irrespective of the static picture and animated clip. Another robotic receptionist study [13][15] incorporated Brown and Levinson's theory to develop a polite strategy with positive politeness. The study applied the bald strategy for the control group in two tasks: a chitchat task and a direction giving task. The polite strategy was positively perceived by the users in both tasks. The implemented polite behavior did not affect the HRI performance in the direction giving task. However, in the chitchat task the polite behavior with a humanoid robot impacted positively the user perception. A study on compliance with a robot in relationship to speech and gesture features that express politeness suggested the need to develop multimodal levels of politeness since too much politeness caused negative impact [14]. The polite gestures, however, were positively associated with the social robot's compliance. In a study in which adaptive feedback was implemented for a companion robot [18] the polite strategy was favored by the male participants while female participants preferred the direct commands. Another study examined the impact of impolite behavior on the performance of the participants in a physical trainer exercise [21]. The researchers found that the impolite robot (which was actually implemented as a rude robot) was not preferred by the participants. However, it yielded improved performance probably since it challenged the users. These studies support the hypothesis that polite behavior is preferred while interacting with a robot. However, all studies used humanoid robots. It is therefore crucial to expand the evaluation of politeness to other types of robots.

The concept of "face" and its implications for politeness rules may not be particularly suitable for human-machine interactions for several reasons. First, the strong emotional content associated with the face concept appears too strong for human-robot relations. Second, politeness based on face-saving strategies relies on verbal communication, whereas much of the interactions between humans and robots rely on nonverbal actions. Third, the face concept is highly sensitive to cultural variations [19] [20]. Furthermore, it is inapplicable to many HRI tasks in which the robot does not include a face (such as industrial and other tasks). Finally, Brown and Levinson's theory is relatively complex, and cannot be easily transformed into HRI design guidelines.

To circumvent some of these issues, Bar-Or et al. [24] proposed a theoretical framework for politeness in the field of HCI which was inspired by Lakoff's theory of polite behavior [3]. In the context of HCI, they demonstrated that polite behavior has a positive impact on user perception and efficiency. However, it remains to be seen whether Lakoff's work can be applied to the design of social robots and its effect on aspects of human-robot interaction.

Lakoff [3] suggests three rules for polite interaction: 1) *Don't impose* your actions or views on other people (at least not without first asking for permission); 2) *Give options* to other people to let them make their own decisions; and 3) *Be friendly* while interacting with other people, in the sense of producing at a sense of equality between the parties. Compared to other prominent politeness theories [25] [26], we consider Lakoff's theory better suited for HRI research because it covers not only nuances of verbal interactions but also more general behavioral communication, which is an important aspect of social robotics. Unlike previous work on politeness in HRI, in which interaction was with a humanoid robot, the current study focuses on **developing and evaluating polite behaviors in collaborative tasks with non-humanoid robots** -- a robotic arm and a mobile robot. Further, we focus on politeness in the interaction itself (and not on polite robot behaviors related to motions and gestures such as approach distance, angle and speed).

To provide a comprehensive analysis of the influence of the robot's polite behaviors, we investigated several parameters as detailed below. For this study, we conducted both live experiments and video-based experiments to try and isolate the effect of the moving robot and focus on the interaction aspects. The current study also includes a diverse population to explore the impact of politeness among different age groups, namely old and young adults. Lastly, we included two tasks (and related robots) to test the impact of polite behavior irrespective of the robot or task.

2.2 Study condition: remote vs. *in situ*.

The Covid-19 pandemic posed serious limitations on our ability to conduct ordinary HRI research. But as sometimes is the case, it also offered an opportunity to enrich the research scope and methods. Therefore, we conducted two types of experiments – one in video, during periods of strict social distancing, and one *in situ*, during periods of relaxation in social distancing measures. Beyond the practical constraints, the use of a remote (video) study was motivated by findings of a previous study [19], which pointed out that participants (old adults) were more focused on the robot actions rather than concentrating on the interaction medium. However, as mentioned above, our goal was to assess people's perceptions of the interaction rather than the robot's physical movements. A video experiment was supposed to mitigate the saliency of physical activity and to help users focus on interactivity. The general guideline for conducting the remote experiment during the COVID-19 pandemic time has been demonstrated in [27]. Previous studies [28][29] suggested that video experiments could be used for exploratory studies in HRI. These studies evaluated the preferable approach direction for a robot in both video and live HRI trials and revealed comparable people's perceptions. However, both studies were limited to a university population which might have influenced the results (in [28], 15 participants aged 21-56 with many of them with computer sciences or robotics background; in [29], 42 university students and staff, aged 18-56). These studies suggested that videos could be used for HRI exploratory studies. Simultaneously, however, they noted limitations – the more the interaction between the robot and the study participant in a trial the less suitable a video would be since it lacks important aspects of the interaction such as dynamics, embodiment, and contingency [29]. Thus, we conducted ***experiments both with a video and a live experiment***. In the video experiment, the users interacted with a robot that was remote from them. In the live experiment, the users interacted with a robot that performed the task in front of them.

2.3 Effect of age and gender on interaction

Effectiveness of assistive robots highly depends upon the acceptance and adoption by the users [30]. Far from the common perception that old adults are wary of technology [31], it was found they are open to new robotic technologies [32] [33]. Attitudes regarding the robot, either regarding the social impact and comfort of the robot or negative towards the robot, were similar in case of old, middle-aged and younger adults [34]. The older old adults (75-84 years) found that a physical training robot ('Gymmy') was more useful as compared to their 65-74 year old counterparts [35]. The older group perceived the robot to be more useful compared to a 65-74 year-old group. As aforementioned, politeness has been explored with different age groups [16]. However, the results did not reveal any significant effect of participants' age on the user perception of the robot.

Nevertheless, in the current work, we relate to the effect of participants' age on user perception. In a person following feedback design study it was observed that perception, preferences and the attitude of users towards the robot highly depends on age and gender of the user [41]. A comparative study between a real and virtual humanoid robot [42] revealed that a greater number of old adults complied with the real robot and had positive impression of both robots but felt more attached to the virtual robot. A survey aimed to assess preferences of robot tasks among old and young adults found that old adults anticipate more benefits of monitoring-type robots [43]. Another study with old and young adults interacting with a humanoid robot in a cognitive training task revealed that the design of the robot and interaction should be adapted to the user's age and needs [44]. A previous preliminary study [19] in which we implemented polite behaviors for a robot manipulator revealed that young adults were able to differentiate between politeness levels. However, the old population was not able to do so. Both populations, though, indicated a preference for the polite behaving robot. All the above, barring one [16], suggested age is a relevant factor of interaction in HRI.

Previous research pointed out that gender plays an influential role in developing a perception about the behavior of the robot [16] [18][35][36][37][38][39][40]. These studies suggested that male and female participants perceive the interaction with the robots differently. On the one hand, it has been suggested that male users are more aware of technological advancements than female counterparts [39]. Hence, male users tend to adapt to usage of robots more easily. This was also supported in [16], which was discussed in previous section, and included a comparison between male and female participants. The study found that the male participants perceived the polite robot more positively than female participants. On the other hand, [40] have found that female participants perceived the interaction with the robot more positively than male users, whereas in the polite gatekeeper the effect of gender on users perception was not significant [16]. Based on these ambiguous findings, we expected that gender would have no effect in our study.

2.4 Type of robot or task

HRI taxonomy is classified into three categories: interaction context (e.g., field of application, type of interaction), robot (e.g., task of the robot, morphology) and team classification (e.g., role of each agent, composition of the team) [45]. In Section 2.2, we discussed the interaction context, specifically with an experiment in video and live conditions. In addition, this work involves ***the usage of different types of robot*** i.e., mobile and manipulator. Previous research mostly concentrated on comparing different anthropomorphic type robots [46, 47]. However, since the type of robot and task influences the interaction [48] it is important to consider this in the evaluation. Hence, we evaluated the effect of polite levels in two different robot tasks/types.

The task of both robots was to bring the utensils for table setting. However, there was a difference in the task type performed by the robot. In one case, the robot manipulates the utensils in the environment to achieve its goal (using the manipulator the robot brings the utensils in front of the user). In the other case, the robot transports the utensils from one place to another (the mobile robot transports the utensils from one room to another where the user is sitting).

2.5 Research questions

The present study aims to investigate the influence of polite robot behaviors on HRI evaluations when using different types of robots (stationary and mobile), in varying conditions (video and live), and in different age groups (old adults and young adults). The following questions were investigated in all four studies:

1) Are participants able to perceive the differences in polite levels (irrespective of robot type, study condition, and age and gender)?
2) Do participants prefer the polite behavior of the robot (irrespective of robot type, study condition, and age/gender)?

Though previous research revealed that differences in some measures depend on the type of robot or task, the overall level of automation had an effect on the interactions irrespective of the robot or task [48]. Further research showed a similar impact of video and live experiments on how users perceived the interactions with the robot [25] [26]. Additionally, previous research [16] points out that the polite behavior of the robot was preferred irrespective of the participants' age. Using Lakoff's politeness rules as a blueprint for the design of interactive robots, we believe that participants would be able to find the difference between the three different polite behaviors and that they will prefer the politest behavior irrespective of their age, type of robot, and experimental condition.

3. **Methodology**

3.1 Model and design

Based on Lakoff's theory of politeness, three different levels of robot politeness in human-robot interaction were developed for a table setting task and implemented with two different types of robots (a robotic manipulator and a mobile robot) as follows:

Three rules polite level - all three rules ("*don't impose*," "*give options*," "*be friendly*") were applied.

One rule polite level – only the "*don't impose*" rule was applied.

No rules polite level – none of the framework's rules was applied, although the robot did not explicitly or ostentatiously violate them.

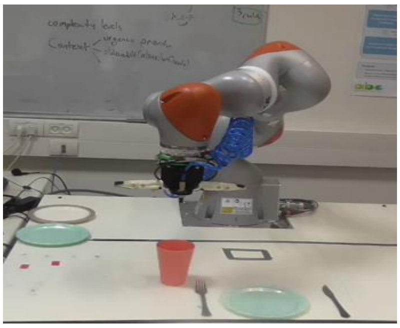
3.2 Experimental setup

Both robots were programmed in Python and executed on ROS (robot operating system). In both experimental setups, the three different polite levels were represented by three different colored buttons on a specially designed GUI. A green colored button represented "no rules" polite level, a blue colored button represented "one rule" polite level, and a red colored button represented "three rules" polite level. The participants were not aware which color represented which level. Each participant went through all politeness levels: In the video experiment, the options were pre-selected in random order. However, in the live experiment, the user had to choose each option. Three videos of each trial (representing three levels of politeness for each of the two robots) were recorded for the video experiment. All the experiments were approved by the university ethical review process.

Robot manipulator. A table setting task was designed with a KUKA LBR IIWA 14 R820 (7 degrees of freedom) manipulator. A TCP/IP protocol was developed for communication between the GUI and the robot. The participant had to interact with the GUI as shown in Fig. 1(a). The robot offered two options for setting the meal -- either a meat meal or a dairy meal[1]. In each setting, it would bring a plate (either dairy or meat plate), a cup, a fork and a knife, as shown in Fig. 1(b). The suction and the gripper were mounted on the robot to pick up the utensils. The three different polite behaviors are described in [19] and in Table 1.

[1] There are different types of utensils for meat and dairy meal according to the common religious practice in Judaism.

(a) Participant while interacting with the robotic arm in a table setting task



(b) Robot setting the table with utensils

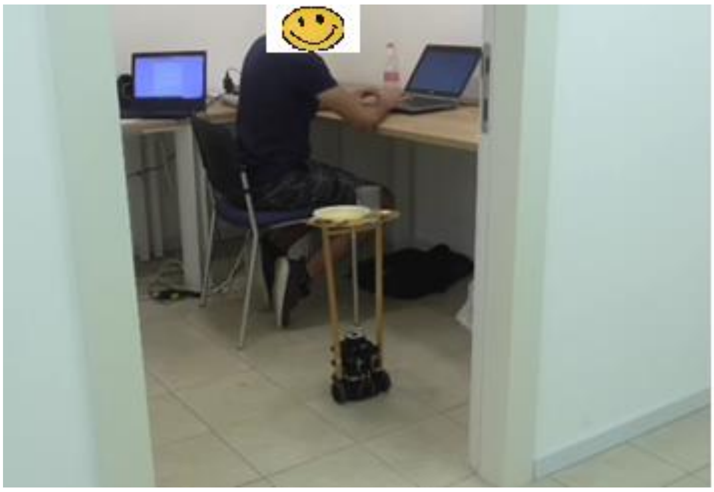
Fig. 1 Manipulator robot experiment

Table 1 The GUI of the screen communicating with the user in manipulator robot experiment

Politeness level / Function	**No rules polite level**	**One rule polite level**	**Three rules polite level**
Start	The robot starts setting up the table. Display: Setting the table.	Display: Do you want to set the table now? Option 1: Yes Option 2: No If option 1 is selected - the next window appears (Type of meal). If option 2 is selected – a time counter of 60s is activated. At the end the same window re appears.	Display: Hello I am robot KUKA. I would be happy to set the table for you. Option: Next New window appears after selecting Next. Display: When do you want to set the table? Option 1: Now Option 2: In a minute Option 3: In two minutes If option 1 is selected – the next window appears. A time counter is activated for options 2 and 3 according to selection and then the window re appears.
Type of meal	Dairy	Display: Do you want the robot to set meat meal utensils? Option 1: yes Option 2: No If option 1 is selected – the robot brings meat meal utensils. If option 2 is selected- the robot brings dairy meal utensils. Display: Setting the table.	Display: Would be happy to know what kind of meal you prefer to set the table for? Option 1: Meat Option 2: Dairy Option 3: I don't care The robot brings respective utensils based on options 1 and 2. For option 3 it brings dairy utensils. Display: Setting the Table.
Stop	Display on screen: Finish	Display: Are you satisfied with the set table? Option 1: Yes Option 2: No If option 2 is selected - the robot exchanges plates. Display: Finish.	Display: I am finished with setting the table. Are you satisfied with arrangement? Option 1: Yes (with thumbs up emoji). Option 2: No, I would rather change the plates (with thumbs down emoji). If option 2 is selected - the robot exchanges plates. Display: Thank you very much. Bon appetite.

Mobile robot. A small mobile robot (Turtlebot3 Burger with two motorized wheels and a LIDAR used for navigation) was used to bring dishes and cutlery for the table setting task. To bring the utensils, a wooden structure with a tray on top of it was mounted on the robot, as shown in Fig. 2 (a) and (b). The height of the wooden frame was 42 cm, and the diameter of the tray was 29 cm. The interface was developed in HTML and JavaScript. The dialogue communicated by the robot to the user is described in Table 2. The difference in this experiment was that the robot asks about the number of utensils required to set the table (according to the number of people dining) instead of asking about different types of meal and the time required to set the table (as in the case of the manipulator robot experiment). In the case of manipulator robot, the participant could easily differentiate between the types of meal as the utensils were present in front of them. However, in the mobile robot experiment the robot would move outside the experimental area to bring the utensils, hence the option of number of utensils was chosen for this experiment.

(a) Turtle bot with mounted tray.



(b) In-person experiment with the turtle bot.

Fig. 2 Mobile Robot Experiment

Table 2 The GUI of the screen communicating with the user in the mobile robot experiment

Politeness level / Function	**No rules polite level**	**One rule polite level**	**Three rules polite level**
Start	The robot would go and bring the utensils. Display: Bringing the utensils.	Display: Please click start to bring up a set of utensils. After pressing start the robot would bring the utensils. Display: Bringing the utensils	Display: Hello! I'm a robot helping to serve the utensils to the table. Please click "Start" when you are ready. Next window appears after choosing Start.
Number of people	For one person	For one person. After bringing the utensil, there would be display on screen: Please click start to bring another set of utensils. Buttons: “Start” or “Finish”. If Start is pressed the robot would bring another one, else would finish the task.	Display: How many people do you want me to bring utensils for? Option 1: For one people Option 2: For two people After one of the above options is clicked the robot would bring the utensil depending on the option selected. Display: Bringing the utensils.
Finish	Display on screen: Finish	Display on screen: Finish	Display: Do you want me to bring another set? Option 1: Yes Option 2: No If option 1 is selected it would bring another set and then task is finished. If option 2 is selected the task is finished. Display on screen: “Thank you very much”.

3.3 Procedure.

Video experiments.

We sent the video experiments’ participants a zoom link (a video conference environment) to connect with the experimenter. Once connected, the participants first gave their consent and then filled out the preliminary questionnaire (the consent instructions and questionnaire were prepared in Google Forms and the link to the form was shared with them). We explained the task and asked them to watch the videos. The videos were presented in a different order for each participant to maintain the random effect. After watching each video, we asked the participants to fill the post-trial questionnaire (see Appendix), and by the completion of the experiment they answered the final questionnaire (see Appendix).

Live experiments.

After arriving at the experiment area, the participants were asked to sign a consent form. Then they were asked to fill a preliminary background questionnaire. The participants were then briefed about the experiments with the robot. They were free to start with any color (on the aforementioned GUI) to maintain randomness and were not informed about the representation of each color. After clicking one of the colored buttons, the robot performed its task according to the chosen scenario. After completing the task in a particular scenario, participants were asked to fill the post-trial questionnaire (see Appendix). On completion of all the three scenarios, participants were asked to fill the final questionnaire (see Appendix).

3.4 Participants.

Overall, 203 people participated in the eight experiments, of whom 97 participated in the four manipulator experiments and 106 in the mobile robot experiments. The age and gender of all participants are detailed in Table 3. Old adults were recruited through online advertisement in social media, snowball sampling and personal telephones to participants who participated in previous experiments in our lab. Young adults were recruited through online advertisement in a mandatory academic course; participation was voluntary, and every participant received compensation in the form of a bonus point contributing to a credit in the academic course. All young adults had experience with both computers and robots. The young adult participants in the live experiment were invited to the university. In the case of old adults, the experimenter visited the participants' homes in accordance with the restrictions during the COVID-19 pandemic. The video experiment was conducted via zoom for both populations because of the limited access

Table 3 Participants age and gender in the experiments

Experiment	Robot Type	Sample	Type	Sample size	Age (avg ± std)	males	females
1	Manipulator	Young adults	Live	30	25.87 ± 5.62	11	19
2			Video	27	25.67 ± 1.84	12	15
3		Old adults	Live	20	73.85 ± 4.99	8	12
4			Video	20	75.31 ± 4.41	10	10
5	mobile robot	Young adults	Live	22	26.45 ± 2.53	11	11
6			Video	44	25.45 ± 1.61	22	22
7		Old adults	Live	20	69.38 ± 3.20	7	13
8			Video	20	70.20 ± 3.75	10	10

4. Results

The post-trial questionnaire included three subjective measures: enjoyment, satisfaction, and trust. The items related to the measures are detailed in the Appendix.

The average for each measure was computed if there was more than one item related to the measure. The questionnaires were intentionally kept short to avoid participants' fatigue along the experiment (there were three interacting sessions with the robot for each participant). The items were selected from various sources including the HCI domain, e-commerce, autonomous vehicles and assistive robotics and were adapted to the current study.

The items for enjoyment were adapted from [24][49][50][51]. The items for satisfaction were adapted from [24][52]. The items for trust were adaptations from [53] on assistive social agents and [54] on autonomous vehicles. The items in post-trial questionnaire A were used only for the live experiment with the manipulator robot, which included two groups (see Table 3) and conducted before COVID-19 pandemic. While reorganizing our research plan amidst the pandemic outbreak, we found that there was a need to shorten the questionnaire and revise some of the questions. This resulted in post-trial questionnaire B that was used for the rest of the experiment. Post trail questionnaire B includes 2 items of enjoyment (between item correlation = 0.69), one item of satisfaction and two items of trust (between item correlation = 0.82). The fact that questionnaires were not identical is a limitation. However, the results from the first two studies are consistent with the rest of the studies, suggesting that the dependent variables' essence was captured similarly by both questionnaires.

Descriptive statistics (mean and standard deviation) were computed for each of the dependent variables. Further, the two-sample Kolmogorov-Smirnov test was conducted on each dependent variable to check for normal distribution. Results revealed that all three dependent variables i.e., enjoyment ($D = 0.15$, $p < 0.001$), satisfaction ($D = 0.18$, $p < 0.001$) and trust ($D = 0.20$, $p < 0.001$) were not normally distributed. Hence, we conducted ordinal regression with a cumulative link mixed model. To compute ordinal regression, the response evaluated from the dependent variables were rounded to the nearest integer resulting in 5 ordinal levels (strongly agree, agree, neutral, disagree and strongly disagree).

The independent variables were defined as participants' age, study condition, type of robot and level of polite behavior. The model was fitted with stepwise elimination using the "buildmer" [55] package in R studio. The scores received from the participants were labeled according to all the independent variables. The regression analysis adjusted for the different sample size of the various experimental groups. Post-hoc test was conducted using least square means with Bonferroni correction. The level of significance (α) was set to 0.0167 after Bonferroni correction.

In addition, to evaluate whether polite behavior is preferred, a logistic regression was computed in which the dependent variable was the preference for the polite level, as expressed in the final questionnaire. The three different levels of politeness were divided to (1) polite behavior ("three rules" polite level) and (0) "ordinary" behavior ("one-rule" and "no rules" polite levels). The participants' age, type of experiment and type of robot were the independent variables. The model was fitted in stepwise elimination using the "buildmer" package[55] .

The results are presented for each dependent variable, namely enjoyment (section 4.1), satisfaction (section 4.2), and trust (section 4.3). This section also includes the discussion on preference (section 4.4) among the three levels based on age, type of experiment, and study condition. Results revealed that gender did not have a significant effect on any of the dependent variables (Enjoyment z-ratio = 1.634, $p = 0.1022$, Satisfaction z-ratio = 1.417, $p = 0.1564$, Trust z-ratio = 1.792, $p = 0.0731$ and preference z-ratio = -1.113, $p = 0.2657$). Consequently, we do not elaborate on this variable in the subsequent analyses.

A detailed analysis conducted for each independent variable, namely different levels of politeness, participants' age, study condition, and type of robot/task is presented in the discussion section.

4.1 Enjoyment

Most participants enjoyed the interaction when the "three rules" polite level was employed, as shown in Fig. 3 (the percentage of people agreeing or disagreeing with the questions after averaging and rounding it to nearest integer related to enjoyment). Less participants enjoyed the interaction with the "one rule" level as shown in Fig. 3. Further, in the "no rules" polite level the least number of participants enjoyed interacting with the robot as shown in Fig. 3. The mean and the standard deviation in case of enjoyment is reported in Fig. 6. More people in the live format (27.2% in strongly agree, 46.0 % in agree, 16.7 % in neutral, 8.3% in disagree, and 1.8% in the strongly disagree category) enjoyed the interaction with the robot as compared to the video format (13.5% in strongly agree, 57.4% in agree, 12.3% in neutral, 13.5 % in disagree, and 3.3 % in strongly disagree category) enjoyed the interaction with the robot. The significant explanatory variables for fitting the ordinal regression model were study condition (video vs live) ($z = -2.43$, $p = 0.015$), participant's age ($z = -2.15$, $p = 0.032$) and levels of polite behavior (one rule compared to no-rule: $z = 5.33$, $p < 0.001$ and three rules compared to no-rule: $z = 8.34$, $p < 0.001$). However, the age of the participants was not significant ($p > 0.017$), hence it was eliminated from the model. The post hoc test for the within groups found that participants easily differentiated between the three different polite levels (see Table 4).

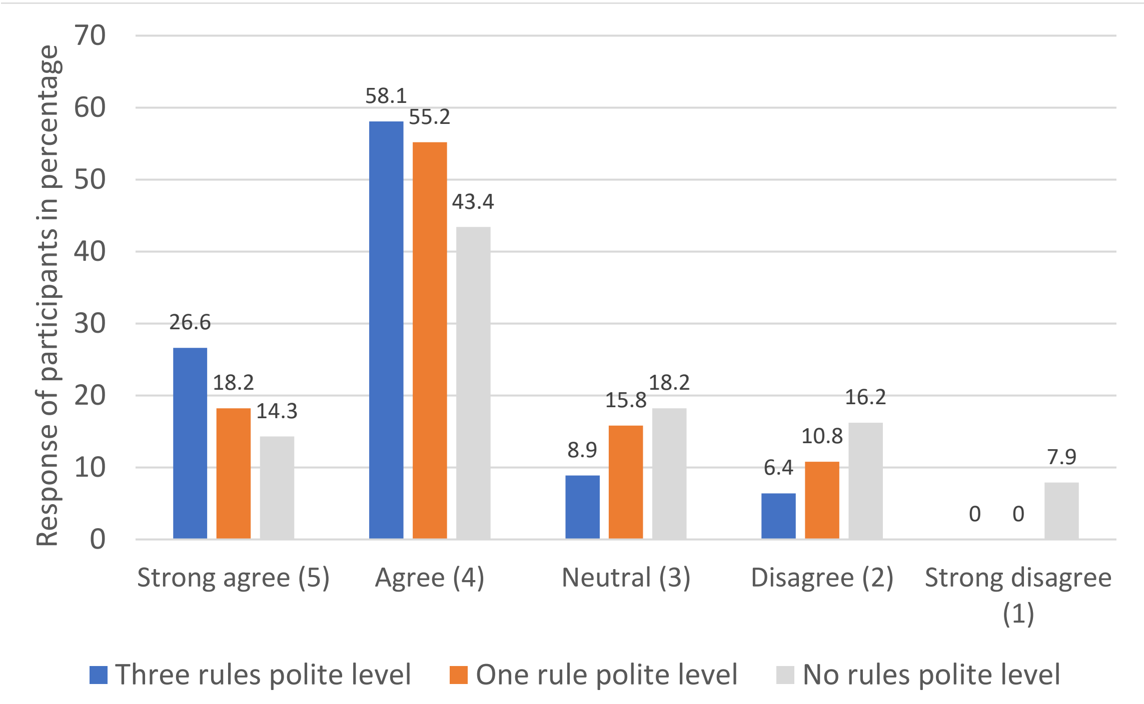


Fig. 3 The participants' responses to the enjoyment items in different polite levels (in percentage).

4.2 Satisfaction

Most participants were satisfied while interacting with the robot at the "three rules" polite level shown in Fig. 4 (the percentage of people agreeing or disagreeing with question related to satisfaction). Less participants were satisfied while interacting with the robot employing "one rule" polite level shown in Fig. 4. The least number of participants were satisfied interacting with the robot employing "no rule" polite level shown in Fig. 4. The mean and standard deviations are reported in Fig. 6. More participants were satisfied while interacting with a mobile robot (32.4 % in strongly agree, 54.4% in agree, 4.1% in neutral, 7.6% in disagree and 1.5% in strongly disagree category) as compared to the manipulator (23.0% in strongly agree, 40.6% in agree, 18.6% in neutral, 14.4% in disagree and 3.4% in strongly disagree category). The independent variables i.e., level of polite behavior (one rule compared to no-rule: $z = 86.97$, $p < 0.001$ and three rules compared to no-rule: $z = 127.33$, $p < 0.001$) and the type of robot ($z = 86.82$, $p < 0.001$) were best fitted for the ordinal regression model. The post-hoc test reflected the difference in all the three levels when pairwise comparison was taken as reported in table 4. The post hoc test revealed that participants easily differentiated between the three different polite levels.

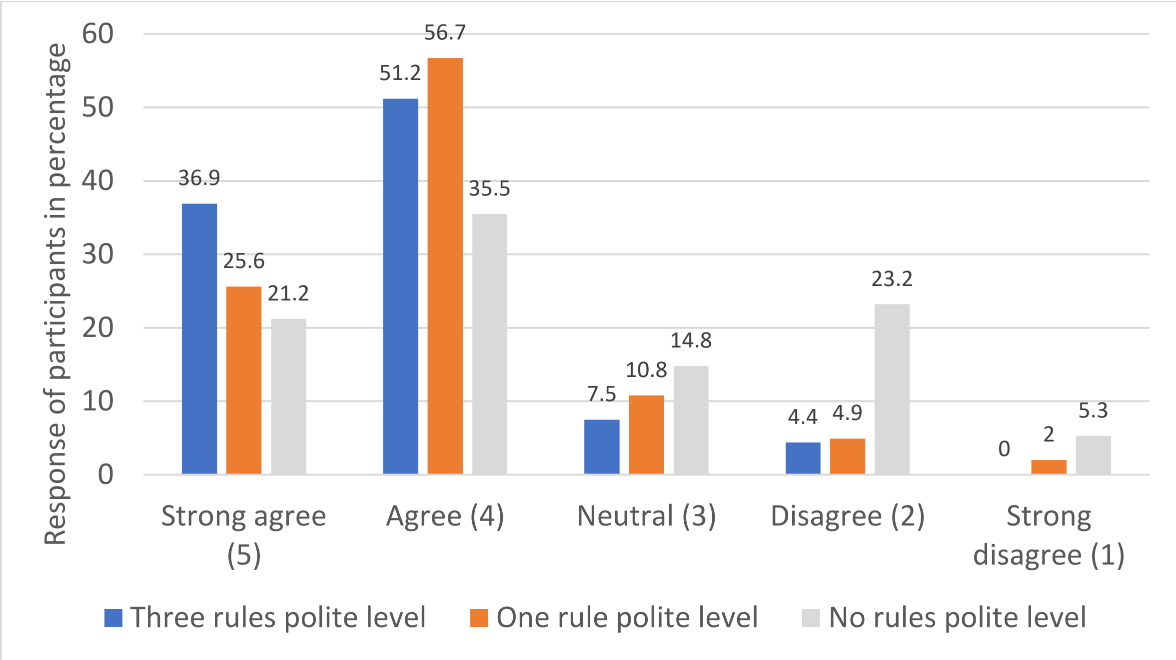


Fig. 4 The participants' responses to the satisfaction item in different polite levels (in percentage).

4.3 Trust

It was found that most participants trusted the robot when the "three rules" polite level was employed by the robot as shown in Fig. 5 (the percentage of people agreeing or disagreeing with questions after averaging and rounding to nearest integer related to trust). Most participants also trusted interacting with the robot when the "one rule" polite level was employed as shown in Fig. 5. Least participants found the robot with "no rule" polite level to be trustworthy as shown in Fig. 5. The descriptive statistics for trust in all three different levels of polite behavior is represented in Fig. 5. It was observed that in the live experiment (30.8% in strongly agree, 55.1 % in agree, 8.7% in neutral, 4.7% in disagree and 0.7 % in strongly disagree category), participants found the robot more trustworthy compared to the video experiment (20.4% in strongly agree, 52.9 % in agree, 11.7% in neutral, 14.1% in disagree and 0.9 % in strongly disagree category). Old adults (34.2% in strongly agree, 48.8 % in agreeing, 10.0% in neutral, 5.8% in disagree, and 1.2% in strongly disagree category) found the robot more trustworthy compared to young adults (19.2% in strongly agree, 57.2 % in agree, 10.6% in neutral, 12.5% in disagree and 0.5 % in strongly disagree category). The regression analysis revealed that polite behavior levels (one rule compared to no-rule: $z = 4.76$, $p < 0.001$ and three rules compared to no-rule: $z = 5.67$, $p < 0.001$), study condition ($z = -2.82$, $p = 0.0048$) and age of participants ($z = -2.56$, $p = 0.01$) were best fitted model. The post-hoc test for trust within three independent variables appears in Table 4. The results indicate that participants were able to differentiate in most pairwise comparisons except for "one rule" and "three rules" polite behaviors.

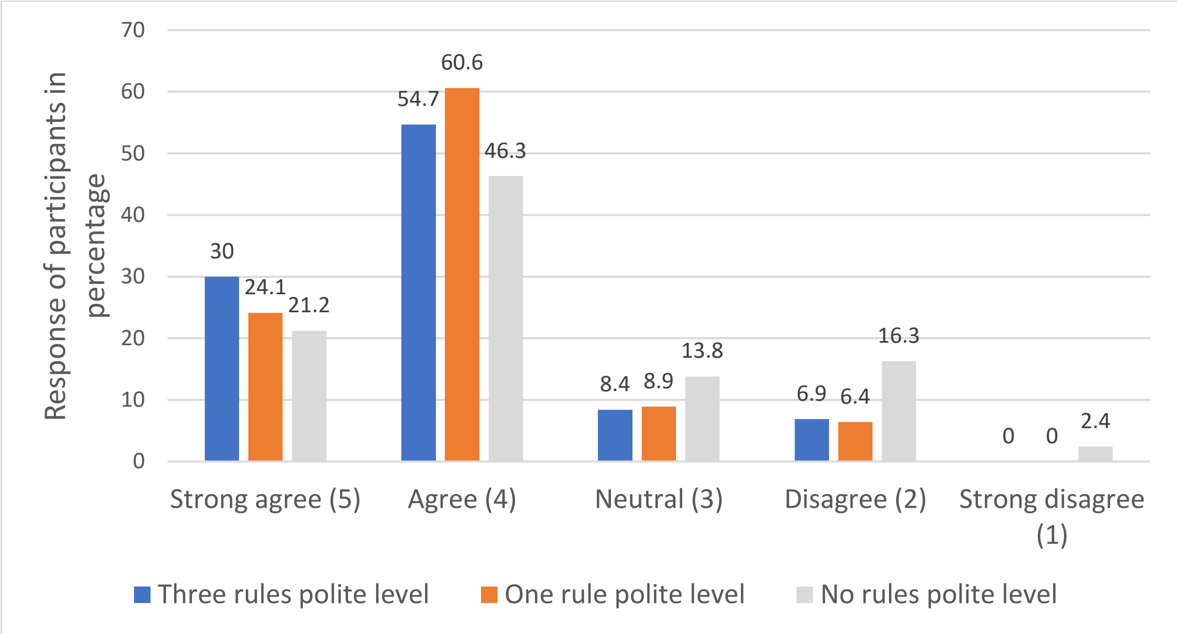


Fig. 5 The participants' responses to the trust items in different polite levels (in percentage).

4.4 Preference

In the final questionnaire, 74.9% of the respondents reported that they noticed the difference between the polite levels. It is evident from Fig. 3 that the three-rule polite level was preferred among the three levels for all three dependent variables. Descriptive analysis of the final questionnaire revealed that 76.4 % of the young adults and 48.8% of the old adults preferred the robot behavior in the "three rules" polite condition, 13.8% of the young adults and 23.8% of the old adults preferred the robot behavior in the "one rule" condition, whereas 9.8 % of the young adults and 27.4% of the old adults preferred the "no rules polite" condition. Logistic regression revealed that age had a significant

Table 4 Post hoc analysis comparing the three polite levels for each dependent measure

Three levels of politeness	Enjoyment	Satisfaction	Trust
No rules vs "one rule" polite	z. ratio = -5.33, $p < 0.001$	z. ratio = -86.91, $p < 0.001$	z. ratio = -4.76, $p < 0.001$
No rules vs "three rules" polite	z. ratio = -8.34, $p < 0.001$	z. ratio = -127.33, $p < 0.001$	z. ratio = -5.78, $p < 0.001$
"One rule" vs "three rules" polite	z. ratio = -3.90, $p < 0.001$	z. ratio = -31.43, $p < 0.001$	z. ratio = -1.21, $p = 0.447$

effect on preference (z = 3. 98, $p < 0.001$). In addition, the following was the participants' response when asked about the *least* preferred condition (Item 3 of the final questionnaire): 64.5% selected the "no rules" polite behavior, 16.8 % selected the "one rule" polite behavior and 18.7% selected the "three rules" polite behavior.

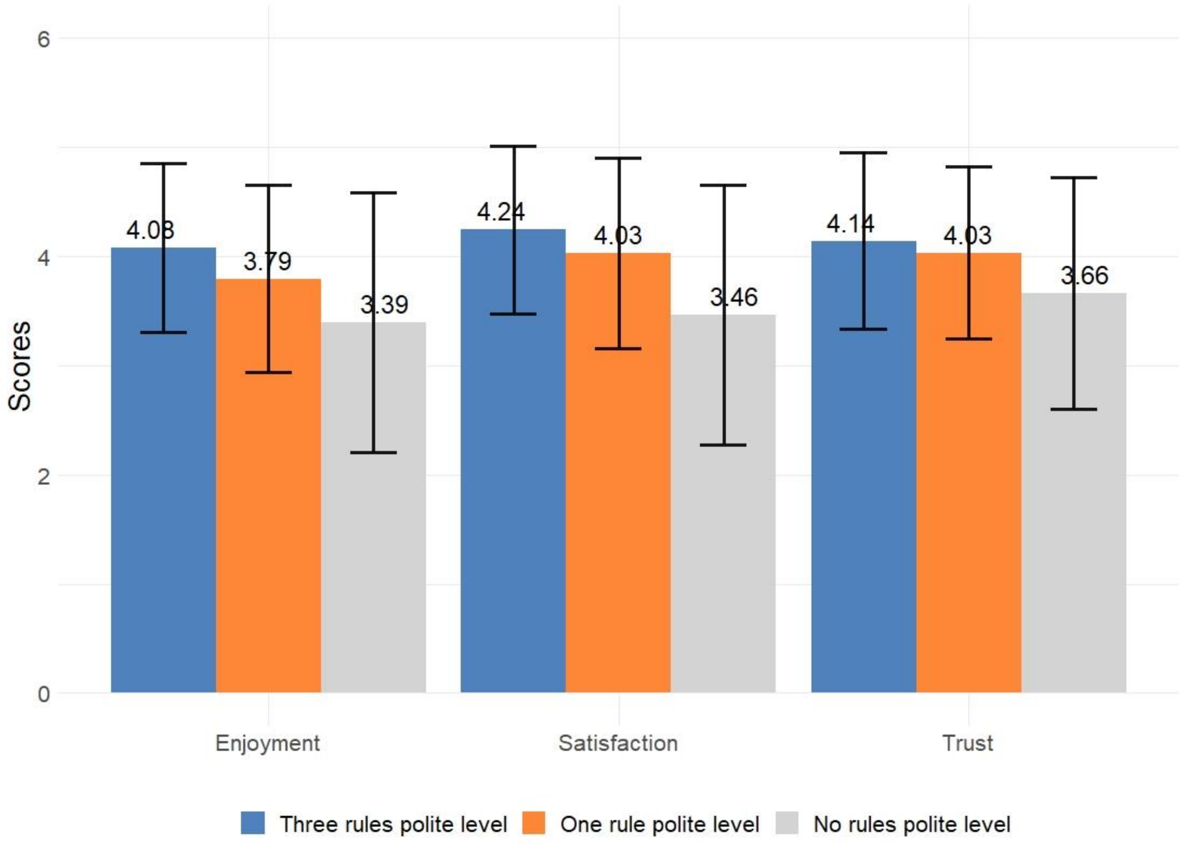


Fig. 6 Mean and standard deviation (error bars) of the independent measures for the different politeness levels of the robots.

5. **Discussion**

To the best of our knowledge, this study is the first to adopt Lakoff's approach to politeness [3] in the domain of social robotics and HRI. The main potential advantages of this approach are its relative simplicity (being based on three fundamental rules) and its applicability to non-verbal interactions. This is especially important in interaction with non-humanoid robots. The results indicate that manipulating politeness according to this approach was successful. Importantly, we tested the generalizability of the findings by using two different robots and two experimental modes – live and by video. Finally, we also tested the effects of age and gender.

The results revealed that robots applying all three politeness rules were rated higher than the other levels on all three dependent variables (enjoyment, satisfaction, and trust). Further, the participants enjoyed the interaction in the live format and found it more trustworthy than the video format. In addition, the participants were more satisfied while interacting with the mobile robot as compared to the manipulator. We also found that old participants had more trust in the robot than the young participants. Contrastingly, more young participants preferred the most polite (the three-rule) robots than old participants. In this section, we discuss the implications of the results in terms of the effects that the independent variables had on users' perceptions and preferences.

5.1 Polite behavior

We developed three levels of polite behavior for assistive, non-humanoid robots, based on Lakoff's (1973) theory. Results from the study demonstrated that participants were able to perceive the difference among the three different polite levels in terms of enjoyment, satisfaction and trust. They also preferred the polite behaving robots. It is evident from the results that most participants preferred the robots that followed the "three rules" condition, although they could not explicitly differentiate between "one rule" and "three rules" polite behaviors in the case of the trust measure. The result in [9] [11], which employed Brown-Levinson's politeness theory [20], showed that polite behavior was not effective in improving HRI performance. Our study demonstrates that participants were satisfied, enjoyed the interaction, and trusted the robot that employed polite behavior. This corresponds to the gatekeeper robot study [16], where most participants preferred the polite behavior condition. However, the gatekeeper robot study lacked interactions with a real robot (it was based on animated interactions to judge the robot's politeness). Further, both aforementioned studies [13] [15] were based on verbal interaction with a robot. However, much of the interaction with the robot is based on its action. A noticeable advantage of using Lakoff's rules is that, as demonstrated in the scenarios used in our study, they are relevant to the non-verbal behavior of assistive robots.

5.2 Study condition: remote vs. *in situ*.

The regression analysis (Sections 4.1 and 4.3) revealed that study condition (remote, video vs in-situ, live) influences enjoyment and trust in HRI. Further, the descriptive analysis (section 4.1 and 4.3) revealed that both in the case of enjoyment and trust measures, participants perceived the live type of experiment more suitable as compared to the video experiment. Previous works ([28] [29]) suggested that video experiments have a similar effect on HRI performance as live experiments. However, the researchers cautioned that video experiments would not be able to replace the live experiments in a more interactive environment. In our work, the enjoyment and trust levels when interacting with a live robot are higher than in the video experiment. Nevertheless, both conditions were useful in revealing the impact of politeness on users' evaluations. Therefore, it seems that both video and live experiments can be used to analyze the impact of social traits in HRI due to their advantages. However, findings from video studies may indicate somewhat weaker effects.

5.3 Effect of age and gender on interaction

The regression analysis (sections 4.3 and 4.4) revealed that the participant's age was a factor in fitting the model of trust in the robot and preference its behavior. The descriptive analysis showed that old adults perceived the robot as more trustworthy compared to young adults. This could possibly be due to their lack of knowledge of possible limitations and failures of robotic technology. Contrary to popular belief of old adults being skeptical of new technologies [31], research has shown that they are more open towards accepting new technologies [32] [33]. The young adults preferred the "three rules" polite behavior over every other polite behavior. As pointed out in [44] the robot's design should be based on participants age and their needs. Though in this study we employed the same design for both age groups. Similarly in [16] the design for all age groups was the same, the participants judged the interaction between an animated gatekeeper robot and an animated person recorded in a clip. However, participants were not directly involved in the interaction with the robot. Hence the age of the participant did not have influence over the user perception. With direct interaction with the robot, the design should be more influential; hence based on [44], we recommend the design to be age specific. In line with [16], in this study participants' gender was not found as an influencing factor.

5.4 Type of robot or task

The regression analysis (section 4.2) revealed that the type of robot and task influenced satisfaction. The descriptive analysis indicates that more participants were satisfied with the mobile robot than the manipulator robot. This is in line with [48], who found that user perception was influenced by the type of robot or task. In the current study, this influence can be explained by the fact that the mobile robot brought all the utensils to the user in one attempt, whereas the manipulator robot brought the utensils one at a time. Since initially the utensils in the manipulator robot task were on the table, easily visible and within reach, the participants may have perceived the robot as slow. Participants complained about the robot's speed in the manipulator robot experiment. Therefore, it is important when evaluating perception about the behaviors of a robot to consider different types of tasks and robots.

6. Conclusions

A series of eight studies examined the consequences of designing polite behavior in non-humanoid robots. Previous HRI literature pointed out that anthropomorphic design of the robot increases the trust of the people in it. However, design complexity increases when incorporating humanoid systems. Further, many robotic applications employ non-humanoid robots. Hence, this study investigated polite behavior in non-humanoid robots.

The design of the robots' behavior was based on the politeness rules introduced by Lakoff [3]. We suggested that these rules could be more easily translated into behavioral guidelines than politeness rules offered by other theories. Our original intent was to assess whether applying those rules of Lakoff to social robots is perceived accordingly and similarly by both young and older people. At an early stage of this research project, our work was disrupted by the outbreak of the Covid-19 virus and the ensuing of social distancing policies and practices. While the disruption hampered and delayed our planned standard in-situ experiments, it presented an opportunity to replicate the same planned studies using video clips and zoom sessions. Thus, we conducted the research in two conditions, video-based studies during times of social distancing and live experiments during periods when restrictions were relaxed. Consequently, we could also examine commonalities and differences in findings in the two conditions

The main contribution of this work is the finding that people can distinguish degrees of politeness in the behavior of non-humanoid social robots designed based on Lakoff's politeness rules. Hitherto research has mainly shown that people perceive politeness in verbal utterances or explicit gestures of humanoid robots. Here, however, we demonstrated the usefulness of our approach in eliciting a sense of politeness merely by designing the non-humanoid robot's mundane interactive behavior.

The issue of age is highly relevant to research on social robotics because we expect different age populations to use social robots for different purposes and because we foresee older adults to be more frequent users of social robots compared to their use of other computing technologies. In general, the results suggest that both older and younger adults perceive politeness differences in the behavior of social robots, although there were some mild differences in proportions. Furthermore, both populations preferred robots that were designed with the three politeness rules over robots that were not designed with any of the politeness rules. Thus, our second contribution is that both older and younger adults value the polite behavior of social robots.

The third contribution relates to the comparison between the in-presence vs. video-based settings of the studies. Similar to previous studies, we found that the participants enjoyed the robots and trusted them more in the live condition. However, we also found that participants in both conditions were sensitive to the politeness manipulations and preferred the more polite versions of the robot. Thus, we suggest that future research on politeness may be less susceptible to the effects of video-based experiments relative to other aspects of HRI research.

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Institutional Review Board Statement: This study was approved by the ethical committee of the Ben-Gurion University of the Negev.
Informed Consent Statement: Informed consent was obtained from all the subjects involved in the study.
Data Availability Statement: The data set generated during and/or analysed during the current study are available from the corresponding author on reasonable request.
Conflict of Interest: The authors declare no conflict of interest.

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Appendix - Questionnaires used in the experiment

Post-trial Questionnaire (A)

To what extent do you agree with the following statements regarding the interaction with the robot in this scenario? (1-5)

1 represents “strongly disagree” and 5 represents “strongly agree”

1. The interaction with the robot was enjoyable. [Enjoyment]
2. During the experiment, I felt that I could rely on the robot. [Trust]
3. During the experiment, I felt that the robot considers my desires. [Satisfaction]
4. During the experiment, I felt that the robot was sociable. [Enjoyment]
5. During the experiment, I felt comfortable with the robot. [Trust]
6. The interaction with the robot was irritating. [Enjoyment, reverse coding]
7. During the experiment, I felt that the robot gave me choices for setting the table. [Satisfaction]
8. Imagine yourself in future when you are required to set a table every day during the week. How much would you like to use the robot in this task? [Satisfaction]

Post-trial Questionnaire (B)

To what extent do you agree with the following statements regarding the interaction with the robot in this scenario? (1-5)

1 represents “strongly disagree” and 5 represents “strongly agree”

1. The interaction with the robot was enjoyable [Enjoyment]
2. I felt the robot could be trusted [Trust]
3. I think that people who will be assisted by the robot will enjoy this interaction [Enjoyment]
4. For this question please select number 2 [Instructional manipulation check]
5. People can trust the robot [Trust]
6. I am satisfied with the way the robot communicated with me [Satisfaction]

Final Questionnaire

1. Did you feel a difference between the scenarios? Yes / No
   If so, what was the difference?
2. How would you like the robot to set the table for you? Green/ Blue/ Red
3. How would you not want the robot to set the table for you? Green/ Blue/ Red
4. In what scenario would you say that the robot was the most polite? Green/ Blue/ Red
5. In what scenario would you say that the robot was the least polite? Green/ Blue/ Red

Items in A were used in the live experiment of young adults and old adults’ manipulator

Items in B were used for the rest of the experimental groups.

Chapter 5. Politeness cannot make up for errors!
Young and old people experiencing collaboration with robots

Politeness cannot make up for errors! Young and old people experiencing collaboration with robots

Eliran Itzhak, Shikhar Kumar, Yael Edan, Galit Nimrod, Vardit Sarne-Fleischmann and Noam Tractinsky

***Abstract*—We investigated the influence of robot politeness and erroneous behavior on users' perceptions in a series of user studies conducted with different robots and populations. Polite behavior for the robot was designed according to Lakoff's theory of politeness. In the four robot conditions that were investigated, we set two different levels of politeness, namely polite (behaving according to Lakoff's politeness rules) and not polite (strict yet not rude behavior), and two levels of error, namely, with and without errors. We conducted three experimental trials with old adults (aged 67-87) and young adults (aged 24-28) and two types of robot (mobile and manipulator). The results revealed that a polite-correct robot was the favorite in all the experimental groups and for most of the participants. Polite but erroneous behavior of the robot evoked a lack of sympathy. It thus appears that politeness cannot make up for errors, and a non-polite behaving robot may even be annoying. In human-robot interaction, in the face of robot errors it is perceived as impolite to be polite!**

Keywords: Polite, Assistive Robot, Old Adults, Human Robot Interaction (HRI), Robot Errors.

I. INTRODUCTION

SOCIAL robots are entering the market at an increasing pace in diverse fields [1]. To ensure efficient collaboration with people, the social robot must be equipped with high-quality human-robot interaction (HRI) skills [1][2]. One such skill, which has seldom been addressed by the HRI literature, is politeness, a quality that serves to increase cooperation and to prevent conflicts. The media equation theory of Reeves and Nass [3] proposed that people respond to computers just as they respond to other human beings. Nass [4] further empirically supported the argument that people tend to behave politely towards the computer. However, these studies did not investigate the important aspect of people's ***expectations*** of polite behavior. Some studies [5][6][7][8] have indeed addressed the question of etiquette interaction between humans and computers, but their theoretical analyses were not examined empirically.

A theoretical framework for defining politeness in the field of human-computer interaction (HCI) was suggested by Bar-Or and Tractinsky (2018). The framework is based on Lakoff's theory of polite behavior [9]. Bar-Or and Tractinsky [10] also demonstrated empirically that polite behavior has a positive effect on efficiency and user perception. The current study was inspired by this line of research and aimed to evaluate the effect of politeness in HRI. Lakoff [9] defined politeness as "a system of interpersonal relations designed to facilitate interaction by minimizing the potential for conflict and confrontation inherent in all human interchange." She suggests that to be polite, one has to follow three sub-rules: 1) *Don't impose* your presence or will on the other person, 2) *Give options* while interacting with the other person, and 3) *Be friendly* while interacting with the other person. Lakoff's theory deals with the behavioral and linguistic aspects of polite communication and is therefore also applicable to human-robot interactions that are not based solely on speech.

In this paper, we report a series of studies that investigated the effects of politeness on users' perceptions of social robots in situations in which the robots' performance could include errors. Previous research [11] has revealed that robot errors have a significant impact over time on people's future beliefs about the robot, namely, users exhibit reduced trust in the reliability of a robot that has made errors. The way in which a robot behaves in response to a failure has a number of consequences: it will affect the willingness of the user to use the robot again [12]; it can lead to a decrease in task performance; and it can reduce the trust that the user puts in the robot and affect how the user perceives the robot [13].

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II. Theoretical Framework and Research Background

A. Politeness

Studies exploring politeness in the field of human-robot interaction (HRI) have produced mixed findings. The research has included studies on humanoid robots (receptionist robot [14]; healthcare service [15]), on an adaptive expressive robot [16] and in animation (gatekeeping robot [17]), with most of these studies being based on the politeness theory of Brown and Levinson [18]. In a receptionist study in which the robot performed as a receptionist, HRI performance was not influenced by the polite behavior [14]. The adaptive expressive robot evoked mixed gender-based responses from the study participants; men expressed a positive perception of polite robot behaviors as opposed to women, who perceived polite behaviors as negative. However, regardless of demographics, all participants in a gatekeeper task preferred the polite-behaving robot [17]. For Nao used as a healthcare service provider robot, a polite gesture with a direct command was preferred to no gesture and indirect commands [15]. A different type of study investigated the influence of impolite behavior in an exercise task with a humanoid robot [19], where impolite behavior was defined as "face threatening behavior," i.e., making a negative comment that could impact the social image of the person undertaking the exercise task. This impolite behavior led to an improvement in the overall performance of the participants, since it was compelling and competitive. However, the participants did not prefer the impolite robot.

In the current research, we investigated the effect of politeness in human-robot collaborative tasks with two types of robot, a mobile robot and a manipulator robot. Based on previous research [20], we formulated only two different levels of politeness, namely polite and not polite (designated 'no-polite'). In the polite behavior condition, all three sub-rules of Lakoff's theory were applied. In the no-polite condition, Lakoff's sub-rules were not implemented. We note that the robot behavior in this condition is closer to being "strict" than the "impolite" version used in ref. [19].

B. Robot Errors

This article also addresses the effect of errors made by the robot on the overall HRI assessment of robot politeness As social robots are increasingly penetrating into our society, research must address, among other factors, erroneous interactions between a human and a robot [21]. Despite the common perception that robots perform error-free actions [22], reality has shown that robots may indeed err. In their detailed survey, Honig and Oron-Gilad [13] proposed a taxonomy for various kinds of failure in HRI. They listed a large number of errors that can happen during human-robot interaction. Since our task is collaborative (detailed in the next section), we focused on errors caused by faulty actions committed by the robot.

Errors serve as a measure of effectiveness in HCIs. Indeed, in the field of HCI, effectiveness is "the accuracy and completeness with which users achieve specified goals" (ISO, 1988). In HRI, effectiveness describes how well a human-robot team accomplishes its goals. This metric normally evaluates the degree to which errors are avoided and tasks are successfully solved [23].

Numerous studies have been devoted to evaluating the effect of erroneous robot behavior on the user [12][21][24][25][26]. In two such studies, faulty robots were perceived as less reliable and less trustworthy than faultless robots (e.g., [24][25]). In the first of these two studies, objective task performance (e.g., a person following the robot) was not affected by the faulty robot [24], but in the other an erroneous robot was perceived as less competent, less intelligent, inferior, and less reliable than an error-free robot [25]. In a study with a non-task-related error, participants perceived the faulty robot as more likable and not less intelligent than the perfectly performing robot [21]. However, a service robot that made an error had a strong negative impact on people's ratings of the service quality [12]. A robot producing incorrect gestures when playing a game (rock, paper, and scissors) with participants was perceived as exhibiting cheating behavior, while verbal cheating was perceived by participants as malfunctioning behavior [26]. Research involving a robot performing checkups of suspected COVID-19 patients arriving at a hospital investigated how transparency and the degree to which a robot made errors affected the users; the results showed a main effect of robot errors on trust, but also revealed that trust depended on the level of transparency [27]. The current research focuses on the importance of politeness as a maxim to be included in the domain of HRI, while taking into account that in the world of social robotics various kinds of robot error can occur during HRI. Therefore, we aimed to explore how politeness maxims affect the collaborative HRI task when the robot errs. In this context, it should be noted that research on human-human interaction has shown that polite behavior contributes to better mitigation practices in the case of error [28]. To date, robot error and politeness have studied separately, but by researching these two constructs simultaneously, we may better understand users' experiences and responses to complex interactions with robots.

C. Research Questions

HRI is influenced by a multitude of variables [29][30], including human variables [31] (e.g., type of user; this research focuses on age and gender), robot variables (types of robot; this research evaluated a mobile robot and a stationary manipulator), task variables [32] (different tasks; this research evaluated the influence in two different tasks) and environmental variables (such as characteristics of the environment, which were not evaluated in this study).

In formulating our research questions, we took into account the mixed results obtained in previous studies on the influence of polite behaviors. In an investigation of correctly performing robots, it was found that the difference between the correct condition and the erroneous condition was counterintuitive, in that participants were significantly closer to the erring robot [33]: It was thought that the significant increase in the likeability of the erroneous robot could possibly be attributed to the novelty of the interaction with such a robot, resulting in increased patience levels [21]. However, in a different study [24], the robot's performance (faulty or correct) did not seem to substantially influence participants' decisions as to whether (or not) to comply with the robot's requests. Additionally, the results suggest that the nature of the task requested by the robot, e.g., whether its effects are irrevocable as opposed to revocable, did influence the participants.

Aiming to explore how politeness and erroneous robot behavior interact, the present study was designed to answer the following questions:

RQ1.1: Is there a difference in the user's perception between the polite and the no-polite robot when the robot performs correctly (does not make any errors)?

RQ1.2: Is there a difference in the user's perception between the polite and the no-polite robot when the robot makes an error?

A preliminary study in which we implemented polite behaviors for a manipulator robot found that young adults were able to differentiate between politeness levels, whereas old adults (66-89) were unable to do so. Nevertheless, both populations indicated a preference for a politely behaving robot [20]. Since previous research revealed that the preferences and attitudes of the users towards the robot depended very much on their age and gender [34] [35] (even though age and gender had no significant effect on participants' impressions of a guard robot's polite features [17]), we decided to investigate this issue in the current research:

RQ2.1: Is age associated with the user's perception of polite/no-polite correct/erroneous performance of human-robot collaboration (HRC) tasks?

RQ2.2: Is gender associated with the user's perception of polite/no-polite correct/erroneous performance of HRC tasks?

Lastly, our third question was formulated in light of studies suggesting that the form and structure of both the robot [36] and the task [31] influence the social expectations of the user [37][29][30]. Therefore, the research focus on questions about a particular aspect of:

RQ3: Does the type of robot influence the user's perception of an HRC task?

III. METHODS

A. Model Implementation

To examine the unique and the combined effects of a robot's politeness and erroneous action on HRI, we conducted experiments with two robot types (robot manipulator and mobile robot) in two different tasks (cube and maze). In each experiment, the user operated the robot in four scenarios that combined the robot's politeness (Polite/No-Polite) and its operation (Correct/Erroneous). Politeness was operationalized based on Lakoff's three sub-rules: '*Do not impose*,' '*Give options*' and '*Be friendly*.' Two levels of politeness were used in these experiments: 'Polite' (all three rules) and 'No-Polite' (none of the rules). The four scenarios corresponded to the all combinations of robot behaviors, namely: No-Polite & Erroneous (NPE), No-polite & Correct (NPC), Polite & Erroneous (PE), and Polite & Correct (PC).

B. Experimental Setup

Manipulator (DOBOT cube experiment)

Each participant interacted with a 4-DOF DOBOT robot via a graphical user interface (GUI) (Fig. 1). The four different scenarios were represented by four different buttons, named "Left," "Left middle," "Right Middle" and "Right" (corresponding to the four scenarios, NPE, NPC, PE, and PC, respectively). The participants were not aware which buttons corresponded to which scenarios. They were informed that they could choose the buttons in any order (Fig. 2). The participants were presented with a screen display of colored cubes and were requested to arrange the colored cubes according to the instructions displayed on the GUI.

In the Polite condition, the robot first greeted the user (adhering to the "*Be friendly*" politeness rule). Then, the robot provided the user with options of different colored buttons corresponding to the different colored cubes (adhering to the "*Give options*," and "*Don't impose*" rules). In the No-polite condition, the robot did not exhibit any of these polite behaviors.

In the Correct condition, the robot presented the colored cubes in an order that would be easy for the user to arrange. In the Erroneous condition, the robot present the colored cubes, but not in the order required for the arrangement.

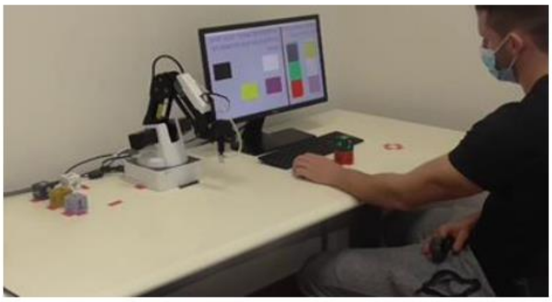

Fig. 1. Participant interacting with the robot

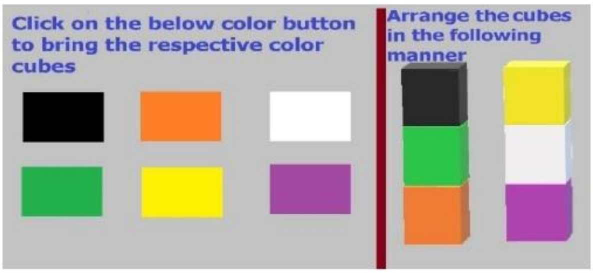

Fig. 2. The GUI for helping the user to choose the specific-colored cubes. The colored buttons are on the left. The instruction for arranging the cubes is on the right.

Mobile robot (waffle maze experiment)

The task in this experiment was to put together a word consisting of three letters that were scattered in a defined environment—in our case, in three different rooms in a maze setup (Fig. 3). The users were instructed to remotely navigate a mobile robot to the three rooms. The interactions between the participants and the robot were facilitated through a GUI (Fig. 4).

During the task, the user did not see the environment directly but rather through a camera installed on the robot. The live video taken from this camera was displayed on the GUI. The experiment included four scenarios (trials) in which the user was required to compose four different three-letter words, with all four words belonging to the same category, e.g., animals. At the beginning of the experiment, the user was informed of the order in which the robot would visit the rooms (the order was identical in all trials). This experiment included the following six rules: 1) each word consisted of three different letters (i.e., there were no duplicate letters); sample words were the Hebrew words for Dog, Sheep, Goat, and Camel (all consisting of three letters). 2) The user was unaware of the letters and the words before the start of each trial. 3) Each of the three letters was stored in a different room, with the rooms being named Blue, Red, and Green. 4) To complete the task efficiently, the robot was required to visit each room in the correct order, which was displayed to the user a-priori, namely, the participant was informed about the correct order of the rooms, but not about the word to be completed. 5) In each scenario, the robot visited each room only once. 6) Finally, based on the letters revealed to the user, the user composed the three-letter word.

The sequence of scenarios (PC-PE-NPC-NPE) was randomly selected (to ensure that there was no order effect) and then assigned to the participants.

In the Polite condition, the robot greeted the participants ("*Be friendly*") at the start of the experiment. The robot further gave the user the option of helping him/her to navigate to each room ("*Don't impose*" and "*Give options*"). In the No-polite condition, the robot did not exhibit any of these polite behaviors.

In the Correct condition, the robot greeted the participants ("*Be friendly*") at the start of the experiment. The robot further gave user the option of helping him/her to navigate to each room ("*Don't impose*" and "*Give options*"). In the Erroneous condition, the robot navigated to each room, but not in an ordered manner.

Fig. 3. The environment in which the robot tours the rooms.

Fig. 4. Participant interacting with the robot.

C. *Participants*

In total, 92 people participated in three experiments. The participants were made up of two distinct populations, young adults (engineering students) and old adults (Table I). Students who volunteered to participate in the experiment received a 1-point credit in an academic course. The old adults volunteered to participate did not receive any compensation.

We were not able to conduct the mobile robot experiment (waffle maze) with the old adults due to COVID-19 restrictions. Hence, we conducted only the manipulator robot experiment with the old adults, since it was convenient and easy for them to participate in their home settings.

Two experiments used the DOBOT robot manipulator. One experiment included 30 students aged 24-28, and the other included 33 participants aged 67-87. The third experiment, the waffle maze experiment, was conducted with 30 students aged 23-35. Due to a fault in the robot operated by one of the male participants, the results of that experiment were not included in the analyses of that experiment.

TABLE I

GENDER AND AGE OF THE PARTICIPANTS IN EACH EXPERIMENT

Experiment designation	# of males	Age	# of females	Age
Waffle young	14	Range: 25-31 Mean = 27 (1.52)	15	Range23-35 Mean=25.67 (2.92)
DOBOT young	15	Range: 25-28 Mean=26.47 (0.99)	15	Range: 24-27 Mean=25.4 (0.91)
DOBOT old	14	Range: 67-85 Mean=77.77 (5.65)	18	Range: 70-87 Mean=78.19 (5.96)

D. *Procedure and Measures*

At the beginning of each experiment, the participants received written instructions about the experiment. After signing a consent form, they provided information regarding their age and gender. Participants in the DOBOT old and Waffle young experiments were also requested to respond to segments of the Technology Adoption Propensity (TAP) [38] and Negative Attitude toward Robots Scale (NARS) [39] questionnaires (Appendix A).

The dependent measures were the user's perceptions of the robot (enjoyment, satisfaction and trust), which were assessed through a post-trial questionnaire (Appendix B). Each measure was represented by two items in the post-trial questionnaire on a 5-point Likert-type scale, ranging from 1 ("Strongly disagree") to 5 ("Strongly agree"). Participants completed the questionnaire after each scenario. At the end of the experiment, they completed a final questionnaire regarding the difference between the scenarios (Appendix C).

E. *Analysis*

The initial analysis evaluated the mean and the standard deviation of all the responses for each of the three dependent measures. A Kolmogorov-Smirnov test indicated that most of the data was not normally distributed (Table II). Therefore, a cumulative link mixed model (CLMM) regression analysis was conducted. The independent variables were defined as the participants' age and gender and the robot's type/task and behavior (PE, NPE, PC, and NPC).

Due to the lack of data, as a result of COVID-19 limitations, comparisons were conducted for subgroups: since the waffle maze experiment included only young participants, our analysis included a comparison between ages only for the DOBOT experiment and a comparison of robot type/task only for the young adult population.

In the Results section, we present the findings for each measure with descriptive and regression analyses. Then, an average analysis of all the participants with respect to age and robot type is presented. We conducted two comparisons, first between old vs. young and second between the mobile robot vs. the manipulator.

As noted above, the order of the robot behaviors was set randomly or was selected according to the specific experiment. To ensure that there was no learning effect, the sequence of scenarios for each participant constituted part of the regression analysis.

The level of significance for all analyses set at 5%. The level of significance (α) was set to 0.0167 after Bonferroni correction. On obtaining a significant result, a post hoc Tukey pairwise test was conducted to determine the significance within the subgroups of the independent variables.

TABLE II
SUMMARY OF KOLMOGOROV-SMIRNOV TEST RESULTS

	Enjoyment	Satisfaction	Trust
Old DOBOT	D=0.24295, p* <0.001	D=0.22643, p* <0.001	D=0.23308, p* <0.001
Young DOBOT	D=0.11007, p=0.1092	D=0.10703, p=0.1279	D=0.18349, p* <0.001
Young Waffle	D=0.20127, p* <0.001	D=0.14759, p* <0.001	D=0.21801, p* <0.001

* Statistically significant

IV. RESULTS

The analyses and the results are organized according to the dependent variables. For each dependent variable, we present descriptive statistics and results of the CLMM analysis for the effects of the experimental condition, the participants' gender and age group, and the robot type. Each analysis tested the following model:

Dependent Variable ~ Robot Behavior + Gender + Age + Robot + (1 | id)

where the last term denotes participants as a random variable. The model was analyzed for each of the three dependent variables (enjoyment, satisfaction, and trust).

In all the analyses, there was no significant effect of gender on any of the dependent variables. In addition, the results revealed no learning effect.

A. *TAP - Technology Adoption Propensity*

The results revealed that 76% of the young and 50% of the old participants noted high self-confidence regarding a general sense of being technological. In addition, 79% of the young and 28% of the old participants believed they could figure out new high-tech products and services without help from others, while 17% of the young and 38% of the old participants had a neutral opinion. Furthermore, 69% of the young and 34% of the old participants reported that they had fewer problems than other people in making technology work, and 21% of the young and 31% of the old participants were indifferent. Among the participants, 69% of the young and 66% of the old reported that they enjoyed figuring out how to use new technologies, and only 14% of the young and 19% of the old said otherwise. Finally, 24% of the young and 18% of the old participants noted that other people came to them for advice on new technologies, whereas 41% and 53%, respectively, disagreed with that statement.

B. *NARS – Negative Attitude toward Robots Scale Analysis*

Most participants, namely, 86% of the young and 56% of the old, did not have negative feelings toward interaction with robots; 4% of the young and 6% of the old were neutral; and 10% of the young and 38% of the old had low negative attitude toward such situations.

C. *Robot Behavior*

In all experiments, participants enjoyed interacting (Fig. 5), experienced satisfaction when interacting (Fig. 6) and trusted (Fig. 7) the Polite-Correct-behaving robot.

From the regression analysis (Table III) it was found, for all the dependent variables, that Polite-Correct was significantly different from the other three combinations, namely, No-Polite-Erroneous and Polite-Erroneous for all the experimental groups, and to No-Polite-Correct in the Waffle experiment. In addition, No-Polite-Correct was significantly different from Polite-Erroneous, and No-Polite-Erroneous for the DOBOT experiment (except enjoyment in DOBOT old experiment). The comparison between No-Polite-Erroneous and Polite-Erroneous gave significantly different results only in the DOBOT old experiment in the trust measure.

TABLE III
SUMMARY OF POST HOC TUKEY PAIRWISE TEST

	Enjoyment			Satisfaction			Trust		
	DOBOT old	DOBOT young	Waffle young	DOBOT old	DOBOT young	Waffle young	DOBOT old	DOBOT young	Waffle young
No-Polite-Correct No-Polite-Erroneous	z=-2.15, p=0.138	z=-5.02, p*=<.0001	z=-0.77, p=0.8690	z=-2.67, p**=0.038	z=-5.56, p*=<.0001	z=-0.55, p=0.9469	z=-3.97, p*=0.0004	z=-5.13, p*=<.0001	z=0.29, p=0.9911
No-Polite-Correct Polite-Correct	z=-0.83, p=0.84	z=-1.45, p=0.4646	z=-2.96, p*=0.0161	z=-1.58, p=0.388	z=-0.58, p=0.9370	z=-3.79, p*=0.0008	z=-1.05, p=0.718	z=-1.43, p=0.4819	z=-3.04, p*=0.0127
No-Polite-Erroneous Polite-Correct	z=-2.97, p*=0.016	z=-5.82, p*=<.0001	z=-3.56, p*=0.0021	z=-4.02, p*=0.0003	z=-5.83, p*=<.0001	z=-3.40, p*=0.0037	z=-4.74, p*=<.0001	z=-6.06, p*=<.0001	z=-2.72, p**=0.0335
No-Polite-Correct Polite-Erroneous	z=3.52, p*=0.0024	z=5.49, p*=<.0001	z=0.91, p=0.8013	z=3.44, p*=0.0033	z=6.28, p*=<.0001	z=0.33, p=0.9879	z=5.94, p*=<.0001	z=6.68, p*=<.0001	z=1.52, p=0.4241
No-Polite-Erroneous Polite- Erroneous	z=1.52, p=0.4258	z=0.72, p=0.8899	z=0.14, p=0.9990	z=0.91, p=0.8002	z=1.41, p=0.4932	z=0.89, p=0.8097	z=3.07, p*=0.0114	z=2.54, p=0.0545	z=1.77, p=0.2860
Polite-Correct Polite-Erroneous	z=-4.25, p*=0.0001	z=-6.24, p*=<.0001	z=-3.65, p*=0.0015	z=-4.67, p*=<.0001	z=-6.51, p*=<.0001	z=-4.05, p*=0.0003	z=-6.39, p*=<.0001	z=-7.07, p*=<.0001	z=-4.19, p*=0.0002

p* - significant; p** - marginally significant

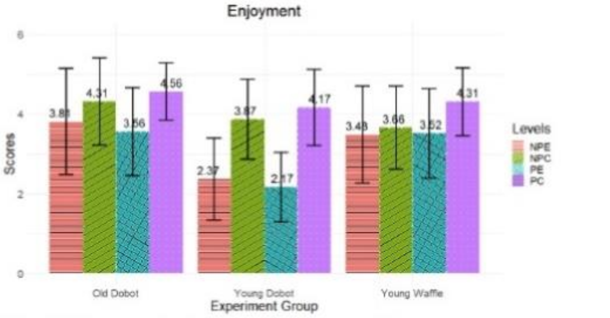

Fig. 5. Mean and standard deviation of the enjoyment measure for the different experiments.

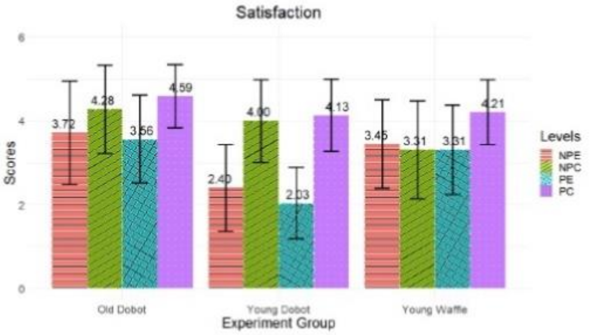

Fig. 6. Mean and standard deviation of the satisfaction measure for the different experiments.

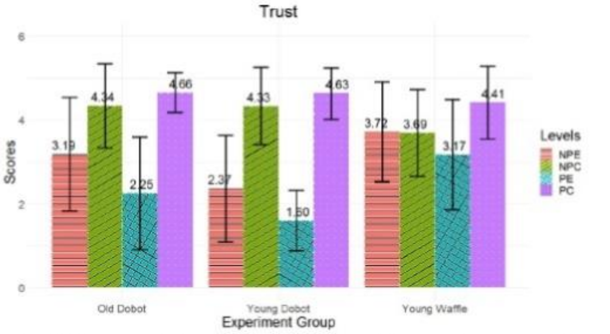

Fig. 7. Mean and standard deviation of the trust measure for the different experiments

D. Participant's Age

The participant's age (young vs. old) had significant influence on all the dependent variables (Enjoyment: $z=-5.1$, $p=3.29e-07$; Satisfaction: $z=-5.18$, $p=2.22e-07$; Trust: $z=-2.0$, $p^{**}=0.0454$), with old adults indicating higher enjoyment (4.09 ± 1.16) than young adults (3.12 ± 1.28), higher satisfaction (4.03 ± 1.12) than young adults (3.12 ± 1.33) and a higher level of trust (3.67 ± 1.29) than young adults ($3.22+1.60$).

E. Robot Type

The robot type (mobile robot vs. manipulator) had a significant influence on all the dependent variables (Enjoyment: $z=3.09$, $p=0.0020$; Satisfaction: $z=2.276$, $p^{**}=0.0229$; Trust: $z=2.56$, $p=0.0105$): operating the mobile robot awarded higher enjoyment (3.77 ± 1.10) than operating the manipulator (3.12 ± 1.28), and higher satisfaction (3.56 ± 1.08) than operating the manipulator (3.12 ± 1.33), and higher trust (3.76 ± 1.17) than the manipulator (3.22 ± 1.60).

F. Preferences

In the final questionnaire, 94% of the old participants and 100% of the young participants were able to distinguish between the scenarios. Polite-Correct was the most preferred scenario for all the experimental groups (47% Old DOBOT, 60% Young DOBOT and 62% Young Waffle).

The least preferred scenario in the DOBOT experiment was Polite-Erroneous (47% old and 57% young), while in the Waffle experiment, 41% of the participants indicated that No-Polite-Erroneous was the least preferred scenario. Additionally, all the participants noted that the Polite-Correct was the politest scenario (53% Old DOBOT, 77% Young DOBOT, 72% Young Waffle). The least polite scenario was Polite-Erroneous (DOBOT experiment 41% old and 43% young), while in the Waffle experiment 31% of the participants noted that the No-Polite-Correct and No-Polite-Erroneous were the least polite scenarios. Finally, all the experimental groups reported that the Polite-Correct was the most enjoyable and the most satisfying scenario, and in that scenario the participants were more confident that they had succeeded in the task.

V. Discussion

Our findings show that in both experiments participants were able to differentiate between erroneous and correct behaviors of the robot (in both types of polite-acting robots) and that they preferred the correct behavior. It should be noted that, contrary to [21], in our case the user's perception about the robot making an error was negative or at least less positive than that of a robot behaving correctly.

The effect of polite behaviors of the robot (while performing correct action) did not have any impact on the users' perception of the robot in experiments in which the manipulator was operated. However, when the mobile robot was operated, there was a preference for a polite robot as compared to no-polite behavior.

In the mobile robot experiment, the user could see the robot's movements only through the camera. In contrast, in the manipulator experiment, the user was sitting close to the robot and could watch all its actions. The participants probably felt more control over the manipulator robot and hence were not influenced by the robot's polite behavior. However, when they could not fully control the robot (since they were remote from the robot) they were skeptical about its' operation .

The ability to differentiate between correct and erroneous behaviors depended on the type of robot. When operating the manipulator, the participants were able to differentiate between correct and erroneous in all scenarios (except for the enjoyment measure for older adults). This finding stands in contrast to previous research suggesting that the robot's performance is of relatively low importance [24]. In the mobile robot experiments, the participants were able to differentiate only between the Polite Correct behavior and all the other behaviors (in all other polite levels they were not able to differentiate between correct and erroneous behaviors). This difference may have resulted from the fact that in the manipulator experiment, participants could repair the mistake when the robot placed the cube while in the mobile robot experiment, as soon as the robot passed a certain room the participant could not access it again. These differences stress the centrality of what may be described as the 'cost of error.' When the error cost is low and can be easily corrected by the user, robot errors are of less significance to the user experience. However, when the error costs are high and difficult (or impossible) to fix, the users are less forgiving, and their evaluation of the collaboration with the robot is harmed.

A commonly held belief regarding age is that old people are more skeptical and hesitant about accepting new technologies [40]. However, our findings showed that the old adults accepted the robots more readily than the young adults in all three dependent variables. This finding supports previous conclusions that the attitude and preference of users toward robots depend on age [34][35] and contradicts previous research [17] that demonstrated that age was not a significant factor in technology acceptance. Overall, this study supports the notion that it is important not to cling to stereotypical user representations [41]. Moreover, age cannot be separated from other factors, such as education and experience with technology. These factors should be considered when developing robotic systems for designated groups to ensure that they meet the needs of the population for which they are intended [42].

The regression analysis revealed that there was a difference in the preference depending on the robot type, with the mobile robot being preferred to the manipulator for all three dependent variables. Several reasons might underlie this difference. First, in the mobile robot experiment the cognitive workload of the participants was higher than that in the manipulator experiment. Second, the perception of robot mistakes might differ according to the way in which the robots were operated: in the manipulator experiment the users were close to the robot and interacted with it via the GUI, which was located near the robot. In contrast, in the mobile robot experiment, the users also interacted via a GUI but did not have a direct view of the robot (they saw the environment through the camera on the GUI).

VI. Limitations

All studies were conducted during the COVID-19 pandemic, with all the attendant problems obviously having some influence on the results (but beyond the scope of this study). However, the pandemic also brings to front the need for such robots which participants became aware of.

VII. Conclusions

Our findings suggest that it is important to evaluate HRI performance for different tasks and robot types with a variety of populations, since the type of user will strongly influence the HRI user perception parameters. More importantly, our results stress the need for research that combines explorations of diverse constructs related to human-robot collaborations, as such studies yield a better understanding of the user experience. In the present study, we simultaneously investigated the effect of designing politeness into robot behaviors and the effects of possible imperfect (i.e., erroneous) robot behavior in real life HRIs. We conducted three 2×2 repeated measures experiments with two factors that manipulated these aspects. The experiments used two types of robot (mobile robot and manipulator) and were conducted with two populations—older adults and younger students. This set of experiments aimed to examine the polite behavior of non-humanoid robots corresponding to Lakoff's polite rules in real-life situations and, at the same time, to examine how humans respond to the erroneous of these robots. The findings show that the Polite-Correct behavior was preferred for both types of robot by both young and old participants, as was evident for all three dependent variables, while Polite-Erroneous behavior received less sympathy. We therefore concluded that although politeness is generally a welcomed robotic quality, it cannot compensate for robot errors. Moreover, when a robot errs, politeness may even annoy the user. This notion should be further studied in additional population groups, using a variety of robots and comparing low vs. high error costs.

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Appendix A – Preliminary questionnaire

Age	
Gender	
Education	High school, Practical Engineer, Bachelor, Master, Ph.D., Others
TAP (technology adoption propensity) Consumers' complex relationships with new technology	I can figure out new high-tech products and services without help from others
	I seem to have fewer problems than other people in making technology work
	Other people come to me for advice on new technologies
	I enjoy figuring out how to use new technologies
NARS (negative attitude toward situations of interaction with robots)	I would feel uneasy if I was given a job where I had to use robots
	The word "robot" means nothing to me
	I would feel nervous/stressed operating a robot in front of other people
	I would hate the idea that robots or artificial intelligences were making judgements about things
	I would feel very nervous/stressed just standing in front of a robot

Appendix B – Post trial questionnaire

Measures	Questions	Reference
Satisfaction	Interacting with the robot was a pleasant and satisfactory experience	Lee, S., & Choi, J. (2017). Enhancing user experience with conversational agent for movie recommendation: Effects of self-disclosure and reciprocity. International Journal of Human-Computer Studies, 103, 95-105.
	I was satisfied with the experience of using a dialogue with the robot to complete tasks	
Trust	The robot was trustworthy	
	I can trust the information provided by the robot.	
Enjoyment	It was fun and enjoyable to share a conversation with the robot	
	The conversation with the robot was exciting	
	I understood what the robot was doing.	

Appendix C - Final questionnaire

Did you feel the differences between the scenarios?
If so, what was the difference?
Which scenario do you enjoy the most?
In which scenario did you feel most confident that you would succeed in the task?
In which scenario were you most satisfied?
Which scenario is better for performing this task?
Which scenario is the least good for performing this task?
In which scenario would you say that the robot was the most polite?
In which scenario would you say that the robot was the least polite?

Chapter 6. Discussion

Creating a successful interaction between humans and robots is a pretty challenging task. To achieve this, robots must be able to communicate naturally with humans both verbally and non-verbally (Breazeal et al., 2016). As robots become more common, it will be important to develop several social skills and methods to evaluate how humans respond to robots (Bethel 2010). This study examined a series of experiments related to the polite design of non-humanoid robots interacting with people in the real-world scenarios. The robot behaviors defined were based on Lakoff's theory of politeness (Lakoff, 1973). The aim of the study was to evaluate the acceptance of polite robots among the participants considering a number of different parameters e.g., age, gender, types of robots / task and experimental conditions.

In the first study which focused on developing, implementing and evaluating polite behaviours for two different robots/tasks the results showed that the participants were able to perceive the difference between the three different levels of politeness in terms of enjoyment, satisfaction and trust. The participants especially preferred the robots who behave politely. This reinforces the claim in the study (Inbar & Meyer, 2019) where most participants preferred polite behavior. However, previous studies (Salem et al., 2013; 2014) that were based on Brown-Levinson's theory of politeness (Brown 1987), showed that polite behavior was not effective in increasing HRI performance. The previous experiments were performed verbally with robots. Withal, much of the interaction with the robot is based on its operation. A notable advantage of using Lakoff's rules is that as demonstrated in the scenarios used in our study, they are relevant to the nonverbal behavior of auxiliary robots. In addition, the experiments were conducted under two conditions (video and live experiments), both conditions proving to be useful in exposing the effect of politeness on user evaluations. Participants reported enjoyment and trust levels when interacting with the robots in live experiments was higher compared to the video experiments. Previous work (Woods et al., 2006) has suggested that video experiments have a similar effect on HRI performance as live experiments but it is not enough to replace the live interaction in a more interactive environment (Woods et al., 2006). Moreover, Both older and young adults were able to differentiate between the three levels of politeness. However, young adults rated higher the “three levels of politeness” (young vs old). In contrast the older adults perceived the polite robot as more trustworthy; This may be due to their lack of knowledge about the limitations and possible failures of robotic technology. In line with the literature, it is necessary to take into account in HRI the individual aspects and special needs relevant of the population (Tapus et al., 2007; Burema 2021). Our research results reveal that the type of robot and task affected the satisfaction, more participants were satisfied while interacting with the mobile robot compared to the manipulator robot. This is consistent with (Olatunji et al., 2021), where during the interaction several parameters were affected by the type of robot or task.

The second study was extended to explore how politeness and erroneous robotic behavior interact. Politeness was defined based on the findings of the first study and included only two polite levels. The experiment was defined as 2x2 repeated measures experiments with two factors that manipulated these aspects with two polite modes (polite and impolite) and operational mode (correct and erroneous) in order to evaluate the interaction in real-world scenarios.

All experimental groups reported that the polite-correct scenario was the most enjoyable and satisfying scenario, and participants were more confident that they would succeed the task. Additionally, we noted the most preferred scenario was the polite-correct of all the experimental groups. In contrast to Mirnig et al. (2017), in our case the user's perception of the erroneous robot was negative, or at least less positive than the correct behaving robot. The differences between correct and erroneous behaviors, was significant in the manipulator experiment (except for the adult pleasure index). This finding is contrary to previous studies suggesting that robot performance is of relatively low importance (Salem et al., 2015). However, in the mobile robot experiment, the difference only existed for the correct polite behaving robot. This may be due to the fact that in the manipulator experiment, participants were able to correct the error when the robot placed the cube near them while experimenting with the waffle, once a particular room passed the participant could not access it again. Also, in this case the age difference was significant, our findings show that old adults have more acceptance for the robot than young adults in all three dependent variables (satisfaction, enjoyment, trust). This finding supports previous conclusions that participants' attitudes and preferences toward robots were age-dependent (Nomura, 2017). Moreover, a difference in preference was observed for the types of robots, in all three dependent variables. The mobile robot was rated high relative to the manipulator. The explanation for this is probably the workload that existed in the experiment with the mobile robot compared to the manipulator and the proximity to the robots (in the manipulator experiment the participants sat close to the robot with direct view while in the mobile robot experiment they watched via GUI what was happening (not near the robot) through a camera that was installed on the robot). In addition, waiting times differed between the experiments. While operating the manipulator robot, participants waited while it brought the item to them. With the mobile robot, on the other hand, participants were always mindful of what might happen while the robot was being operated.

As part of the regression analyses, no significant difference was observed in the parameters of gender and the scenarios sequence performed by the participants.

Chapter 7. Conclusions and future research

The major contributions of this study have yielded a number of conclusions. First, humans can differentiate levels of politeness in the behavior of non-human social robots designed based on Lakoff's politeness rules. So far it has mostly been shown that people perceive politeness in verbal expressions or explicit gestures of humanoid robots. However, here we have demonstrated the usefulness of our approach in creating a sense of politeness only by shaping the interactive behavior of the non-human robot. Second, the age issue is very relevant to research in HRI because we expect different age populations to use social robots for different purposes and because we expect older adults to use social robots more frequently compared to their use of other computing technologies. Moreover, both older adults and young adults appreciate polite behavior of social robots. Another contribution relates to the comparison between the in-presence vs. video-based settings of the studies. Similar to previous studies, we found that participants enjoyed the robots and trusted them more in the live mode. Thus, we suggest that future research on politeness may be less susceptible to the effects of video-based experiments relative to other aspects of HRI research.

So far, robotic error and politeness were studied separately. Hence, robotic polite behavior in real-world scenarios suggests that although politeness is generally a welcome robotic quality, it cannot compensate for robotic errors. Moreover, when the robot is wrong, its politeness may even annoy the user. When making errors it is impolite to be polite!

There are a multitude of factors influencing HRI. In this work we evaluated the influence of age, gender and type of robot in both video and live experiments. Future work should address additional aspects such as task type (e.g., time critical vs. quality; pragmatic vs. hedonic) and environment (crowded/sparse, structured/unstructured), using a variety of robots and comparing low vs. high error costs.

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List of Appendices

Appendix A – Mobile robot Turtlebot3 Burger software code system

https://github.com/E-beginner2020/Table-setting-politeness/tree/main/Table_setting_polite_burger

Appendix B – Mobile robot Turtlebot3 Waffle software code system

Maze-mobile-robot-politeness/maze_mobile_robot_polite at main · E-beginner2020/Maze-mobile-robot-politeness · GitHub

Appendix C – Manipulator software code KUKA system

https://github.com/shikharkumar1993/ESR15-Polite-Robot/tree/master/thepoliteRoboteng

Appendix D – Manipulator software code Turtlebot3 Burger system

https://github.com/E-beginner2020/Dobot-cube-politeness

Appendix E- Study 1

BGU ethical committee

I. General

Name of Research Project: Polite Robot – Developing & Evaluating polite robot scenarios

To which agency is the proposal being submitted (or has been submitted):

Principal Investigator/s (or academic supervisor/s):

Name: Vardit Sarne-Fleischmann	Name: Yael Edan
Department: IE&M	Department: IE&M
Academic position: Phd	Academic position: Prof
University Telephone:	University Telephone:
Mobile Phone:	Mobile Phone:
University Email: varditf@gmail.com	University Email: yael@bgu.ac.il
Other Email:	Other Email:

Name(s) of those conducting the research (if different from above):

Name: Eliran Itzhak	Name:
Department: IE&M	Department:
Academic position: BSc student	Academic position:
University Telephone:	University Telephone:
Mobile Phone: 0538311132	Mobile Phone:
Email: eliranit@post.bgu.ac.il	Email:

II. Consent to Participate

1. Are the subjects able to legally consent to participate in the research? ☒ Yes / ☐ No

If you answered 'No' to question 1, complete section IIb

2. Will the subjects be asked to sign a consent form? ☒ Yes / ☐ No

If you answered 'No' to question 2, explain here:

IIb: Subjects who cannot legally consent (minors, mentally incapacitated, etc.):

3. Will the subject's legal guardian be asked to sign a consent form? ☐ Yes / ☐ No

If you answered 'No', to question 3, please explain here:

4. Will the subject be asked to give oral consent? ☐ Yes / ☐ No

5. Are the instructions appropriate to the subjects' level of understanding? ☐ Yes / ☐ No

Comments: In the case of minors - they will be asked to give oral consent, whereas their parents will be asked to sign a consent form.

6. If informed consent forms will be signed, how will the informed consent forms be stored to ensure confidentiality? All signed forms will be saved in a locked cabinet.

III. Discomfort:

7. Will the participants be subjected to physical discomfort? ☐ Yes / ☒ No

8. Will the participants be subjected to psychological discomfort?: ☐ Yes / ☒ No

If you answered 'Yes' to question 7 or 8, add here a detailed explanation of the circumstances:

IV. Deception

9. Does the research involve deceiving the subjects? ☐ Yes / ☒ No

10. Is the decision on the part of the subject to participate in the study based on deception? (For example, if they are informed of their participation only after the event.) ☐ Yes / ☒ No

If you answered 'Yes' to question 9 or 10, add here a detailed explanation why deception is necessary:

V. Feedback to the Subject

Note: Although feedback to the subject is recommended for *all* studies, it is required for studies that involve discomfort or deception. Feedback entails providing the subject, upon completion of the experiment, explanation of the experiment and its aims.

11. Will the subjects be provided with post-experiment oral feedback? ☐ Yes / ☒ No

12. Will the subjects be provided with post-experiment written feedback? ☐ Yes / ☒ No

If you answered 'No' to both questions 11 and 12, explain here: The goal in the experiment is to find out how different levels of politness effects human robot interaction. This goal requires analysing the data and therefore participants do not receive feedback after the experiment

VI. Compensation for Participation

13. Will the subjects receive compensation for participation? ☐ Yes / ☒ No

Detail here the type and amount of compensation:

If you answered 'No' to question 13, explain the basis for participation: Voluntary

VII. Privacy:

14. Will audio and/or visual recordings be made of the subjects? ☒ Yes / ☐ No

    a. If yes, are they informed of this fact in the informed consent form? ☒ Yes / ☐ No

15. Will the data collected (apart from the informed consent form) contain identifying details about the subjects? ☒ Yes / ☐ No

    a. If the data contains identifying details, please answer here: (1) What steps will you take to ensure the confidentiality of the information? (2) How will the data be stored? (3) What will be done with identifying information or recordings of the subjects at the end of the research? the data will be encoded and will be deleted after the research

VIII. Withdrawal from the Study:

16. Will subjects be informed that they may withdraw from the study at any time? ☒Yes / ☐ No

17. Will the subjects' compensation for participation be affected if they withdraw from the study before its completion? ☐Yes / ☒ No

    a. If yes, are they informed of this fact in the informed consent form? ☐Yes / ☐ No

IX. Research Equipment

18. Does the research entail the use of equipment other than standard equipment, such as computers, video recording equipment? ☒Yes / ☐ No

19. If yes, does the equipment being used meet safety standard for use with human subjects?

☒Yes / ☐ No

Please specify which standards (include documentation where appropriate): The robot which will be used in the study is programmed to avoid collision and to slow down when aproaching any obstacle. Number Safety Standart - EN 60335-1:2012., EN 60335-2-2:2010 + A1:2012.

Signatories:

Name: Yael **Position:**

Signature: ____________ **Date:**

Name: **Position:**

Signature: ____________ **Date:**

Explanation form for the participants

<u>נושא המחקר: אינטראקציית אדם-רובוט</u>

*גוף השאלון מנוסח בלשון זכר מטעמי נוחות והינו מכוון לשני המינים.

מטרת העל של הפרויקט הינה למצוא אילו מאפיינים בהתנהגות הרובוט עלולים להשפיע על האינטראקציה בין האדם לרובוט, כאשר הוא מסייע לו בביצוע מטלות מחיי היום-יום.

השלב הנוכחי של המחקר נערך בשיתוף פעולה עם מרכזי יום/דיור מוגן לאוכלוסיית הגיל השלישי ובבניין 16 חדר 134- באוניברסיטת בן גוריון. המחקר עוסק בגורמים המשפיעים על אינטראקציית אדם-רובוט. משך המחקר כ-שעה.

במסגרת המחקר תידרש לבקש מהרובוט להביא עבורך כלים לעריכת השולחן באמצעות מענה על מספר שאלות שהרובוט ישאל אותך. הרובוט יביא את הכלים לעריכת השולחן שלוש פעמים, כאשר בכל פעם יתנהג בצורה אחרת. במהלך הניסוי תתבקש לענות על השאלות של הרובוט באמצעות בחירה מתוך האופציות שיופיעו במסך. בנוסף, חשוב לנו להדגיש כי מטלת הניסוי היא רק דוגמה למטלה בסיסית מחיי היום-יום בה הרובוט יכול לסייע. כמו כן, הרובוט מיועד לסייע לבן אדם שאין ביכולתו או קשה לו להביא כלים לעריכת שולחן ולכן נסה לחשוב על עצמך במקום הזה.

בתחילת הניסוי תתבקש לענות על שאלון מקדים. לאחר מכן יתבצעו שלושה תרחישים שונים בהם הרובוט יביא את הכלים לעריכת השולחן, כאשר בסיום כל תרחיש תתבקש לענות על שאלון שישקף את תחושותיך מהתרחיש הנוכחי. בסיום שלושת התרחישים תידרש לענות על שאלון מסכם.

לא מתבצעת שמירה של הפרטים המזהים של הנבדקים. כל נבדק מקבל מספר נבדק אשר מופרד מפרטי הנבדק. כל השאלונים יימסרו בתום המחקר לחוקרת הראשית הממונה על המחקר וישמרו באחריותה.

במהלך הניסוי נבצע סרטונים של הניסוי אשר ישמשו אותנו לצורך ניתוחים סטטיסטים. את הסרטונים נשמור תחת תיקיית דרייב אשר הגישה אליה מתבצעת באמצעות קוד, את התצלומים נשמור בתיקייה זו למשך 5 שנים.

אם מכל סיבה שהיא הנך חש שלא בנוח, בבקשה עצור את הניסוי ועורך הניסויים ייגש אליך באופן מידי. בכל עת ובכל שלב תוכל, אם תרצה, להפסיק את השתתפותך במחקר. במידה ורצונך כי הניסוי ייפסק, תשוחרר מהניסוי ללא התחייבות.

Consent form for the participant

<u>נושא המחקר: אינטראקציית אדם-רובוט</u>

נבדק יקר,

בבקשה קרא את דף ההסבר באשר לניסוי. במידה ויש שאלות, נשמח לענות.

בבקשה וודא כי הנך מבין היטב את שלבי המחקר.

להזכירך, המחקר עוסק בגורמים המשפיעים על האינטראקציה בין האדם לרובוט. במהלך הניסוי תידרש לבקש מהרובוט להביא עבורך כלים לעריכת שולחן. משך הניסוי לכל היותר שעה. הניסויים יבוצעו בשיתוף פעולה עם מרכזי יום/דיור מוגן לאוכלוסיית הגיל השלישי.

אני החתום מטה*:

א. מצהיר/ה בזאת כי אני מסכים/ה להשתתף בניסוי, כמפורט במסמך המפרט את חלקי הניסוי.

ב. מצהיר שהוסברו לי בפירוט כל חלקי הניסויי והסכמתי ליטול בו חלק לאחר שנענו כל שאלותיי לגבי כל אחד מחלקי הניסוי.

ג. מצהיר בזאת כי הוסבר לי על-ידי החוקר/ת: ___________________

1) כי אני חופשי לבחור שלא להשתתף בניסוי וכי אני חופשי להפסיק בכל עת את השתתפותי בניסוי מכל סיבה שהיא.

2) במידה ואני חש ברע או באי נוחות במהלך הניסוי חובה עלי לדווח לנסיין על מנת להפסיק את הניסוי.

3) מובטח שזהותי האישית תשמר סודית על-ידי כל העוסקים והמעורבים במחקר ולא תפורסם בכל פרסום כולל בפרסומים מדעיים.

4) מובטח כי גם אם אשתתף בניסוי - תהיה באפשרותי לבקש להפסיק השתתפותי במחקר עד 5 ימי עסקים מסיום הניסוי. במקרה זה, כל הנתונים אודותיי יימחקו.

5) כי באפשרותי לבקש, עד שבוע ימים לאחר תום הניסוי, לצפות בנתונים שנאספו לגביי בניסוי.

6) מובטחת לי נכונות לענות לשאלות שיועלו על-ידי.

7) **במהלך הניסוי החוקרים יצלמו תמונות וסרטונים לצורכי מחקר בלבד.** במידה ואתה מאשר\ת זאת, חתום כאן:_______________

במידה ואת\ה מסכימים שתמונתכם תופיע בפרסומים שונים שיוצגו לציבור אנא ציינו:

☐ אני מסכים שתמונתי תופיע בפרסומים שונים

☐ איני מעוניין שתמונתי תופיע

8) במידה וייערך ניסוי המשך, האם תהיה מעוניין להשתתף בו? כן / לא

(במידה ותאשר, נפנה אליך בהמשך)

שם פרטי ומשפחה:	ת.ז.

חתימה:	טלפון:

*הצהרה זו הינה סודית ואינה ניתנת להעברה או שימוש לצורך שום דבר או גורם אחר פרט לצורכי מחקר זה.

תאריך ________________ חתימת מעביר הניסוי ______________

Preliminary questionnaire

מספר משתתף: (המספר שרשום לכם בקובץ ההרשמה לניסוי ליד התעודת זהות) *

התשובה שלך

גיל *

התשובה שלך

מגדר *

- ◯ זכר
- ◯ נקבה

האם יש בבעלותך מחשב (שולחני, נייד או טאבלט) שאתה משתמש בו? *

- ◯ כן
- ◯ לא

אם כן, מהי תדירות השימוש שלך בו? *

- מידי יום
- כמעט כל יום
- פעם או פעמיים בשבוע
- פעם או פעמיים בחודש
- לעיתים רחוקות
- לא רלבנטי - אני לא משתמש במחשב כלל

ובאילו ישומיים אתה משתמש

- תקשורת עם אחרים באמצעות דואר אלקטרוני, סקייפ וכד'
- חיפוש מידע באמצעות מנועי חיפוש (כגון Google)
- ביצוע משימות כגון קניות, ניהול חשבונבנק, קביעת תורים וכד'
- פעילויות פנאי כגון משחקים, צפיה בסרטונים, האזנה למוסיקה וכד'
- אחר:

האם יש בבעלותך טלפון נייד או שאת/ה משתמש/ת בו? *

- כן
- לא

אם כן איזה סוג של טלפון?

- סמארטפון (טלפון חכם)
- טלפון נייד רגיל (לא סמארטפון)
- לא רלבנטי - אינני משתמש בטלפון נייד

ובאילו ישומיים אתה משתמש?

- דואר אלקטרוני
- פייסבוק
- וואטסאפ
- שיחות טלפון
- הודעות SMS
- ניווט (וייז וכדומה)
- צילום תמונות או וידיאו
- ניהול זמן - יומן, התראות, שעון מעורר
- אחר:

האם יצא לך להתנסות בסוג מסוים של רובוטים? *

- כן
- לא

אם כן, איזה?

התשובה שלך

Post trial questionnaire

תרחיש *

- כחול
- אדום
- ירוק

מספר נבדק *

טקסט של תשובה קצרה

איך אתה מרגיש ביחס לאינטראקציה עם הרובוט

אנא ציין את מידת הסכמתך עם האמירות הבאות, כאשר:
1 - לא מסכים בכלל
2 - לא מסכים
3 - ניטרלי
4 - מסכים
5 - מסכים מאוד

1. האינטראקציה עם הרובוט הייתה מהנה *

	1	2	3	4	5	
לא מסכים בכלל	○	○	○	○	○	מסכים מאוד

2. האינטראקציה התאימה לרובוט המסייע לאנשים המתקשים בתנועה *

	1	2	3	4	5	
לא מסכים בכלל	○	○	○	○	○	מסכים מאוד

3. הרגשתי שניתן לסמוך על הרובוט *

	1	2	3	4	5	
לא מסכים בכלל	○	○	○	○	○	מסכים מאוד

4. לדעתי אנשים להם יעזור רובוט מהסוג הזה יהנו לתקשר איתו

	1	2	3	4	5	
לא מסכים בכלל	○	○	○	○	○	מסכים מאוד

5. עבור שאלה זו נא לבחור בתשובה מספר 2 *

	1	2	3	4	5	
לא מסכים בכלל	○	○	○	○	○	מסכים מאוד

6. אנשים יכולים לתת אמון ברובוט הזה *

	1	2	3	4	5	
לא מסכים בכלל	○	○	○	○	○	מסכים מאוד

7. באופן כללי אני מרוצה מהדרך שבה התנהלה האינטראקציה עם הרובוט *

	1	2	3	4	5	
לא מסכים בכלל	○	○	○	○	○	מסכים מאוד

שליחה

ניקוי הטופס

Final questionnaire

מספר נבדק *

התשובה שלך

1. האם הרגשת הבדלים בין התרחישים שהוצגו בפניך? *

- ◯ כן
- ◯ לא

במידה וכן, באליו הבדלים הרגשת?

התשובה שלך

2. אם היית צריך להשתמש ברובוט כמו זה, באיזה מהתרחישים היית מעדיף/ה להשתמש? *

- ◯ התרחיש הירוק
- ◯ התרחיש הכחול
- ◯ התרחיש האדום

3. אם היית צריך להשתמש ברובוט כמו זה, באיזה מהתרחישים לא היית רוצה להשתמש? *

- התרחיש הירוק
- התרחיש הכחול
- התרחיש האדום

4. באיזה תרחיש הרובוט היה הכי מנומס *

- בתרחיש הירוק
- בתרחיש הכחול
- בתרחיש האדום

5. באיזה תרחיש היית אומר שהרובוט היה הכי פחות מנומס *

- בתרחיש הירוק
- בתרחיש הכחול
- בתרחיש האדום

שליחה

ניקוי הטופס

Appendix F - Study 2

BGU ethical committee approval

Principal Investigator/s (or academic supervisor/s):

Name: Vardit Sarne-Fleischmann	**Name**: Yael Edan
Department: IE&M	**Department:** IE&M
Academic position: Ph.D.	**Academic position:** Prof
University Telephone:	**University Telephone**:
Mobile Phone:	**Mobile Phone:**
University Email: varditf@gmail.com	**University Email:** yael@bgu.ac.il
Other Email:	**Other Email:**

Name(s) of those conducting the research (if different from above):

Name: Eliran Itzhak	**Name**:
Department: IE&M	**Department:**
Academic position: BSc student	**Academic position:**
University Telephone:	**University Telephone**:
Mobile Phone: 0538311132	**Mobile Phone:**
Email: eliranit@post.bgu.ac.il	**Email:**

II. Consent to Participate

1. Are the subjects able to legally consent to participate in the research? ☒Yes / ☐ No

   If you answered 'No' to question 1, complete section IIb

2. Will the subjects be asked to sign a consent form? ☒Yes / ☐ No

   If you answered 'No' to question 2, explain here:

IIb: Subjects who cannot legally consent (minors, mentally incapacitated, etc.): not applicable

3. Will the subject's legal guardian be asked to sign a consent form? ☐Yes / ☐ No

   If you answered 'No', to question 3, please explain here:

4. Will the subject be asked to give oral consent? ☐Yes / ☐ No

5. Are the instructions appropriate to the subjects' level of understanding? ☐Yes / ☐ No

Comments: In the case of minors - they will be asked to give oral consent, whereas their parents will be asked to sign a consent form.

6. If informed consent forms will be signed, how will the informed consent forms be stored to ensure confidentiality? All signed forms will be saved in a locked cabinet.

III. Discomfort:

7. Will the participants be subjected to physical discomfort? ☐Yes / ☒ No
8. Will the participants be subjected to psychological discomfort?: ☐Yes / ☒ No

   If you answered 'Yes' to question 7 or 8, add here a detailed explanation of the circumstances:

IV. Deception

9. Does the research involve deceiving the subjects? ☐Yes / ☒ No
10. Is the decision on the part of the subject to participate in the study based on deception? (For example, if they are informed of their participation only after the event.) ☐Yes / ☒ No

    If you answered 'Yes' to question 9 or 10, add here a detailed explanation why deception is necessary:

V. Feedback to the Subject

Note: Although feedback to the subject is recommended for *all* studies, it is required for studies that involve discomfort or deception. Feedback entails providing the subject, upon completion of the experiment, explanation of the experiment and its aims.

11. Will the subjects be provided with post-experiment oral feedback? ☐ Yes / ■ No

12. Will the subjects be provided with post-experiment written feedback? ☐ Yes / ■ No

    If you answered 'No' to both questions 11 and 12, explain here: The goal in the experiment is to find out how different levels of politness effects human robot interaction. This goal requires analysing the data and therefore participants do not receive feedback after the experiment

VI. Compensation for Participation

13. Will the subjects receive compensation for participation? ☐ Yes / ■No

    Detail here the type and amount of compensation:

    If you answered 'No' to question 13, explain the basis for participation: Voluntary

VII. Privacy:

14. Will audio and/or visual recordings be made of the subjects? ■ Yes / ☐ No

    a. If yes, are they informed of this fact in the informed consent form? ■Yes / ☐ No

15. Will the data collected (apart from the informed consent form) contain identifying details about the subject? ■Yes / ☐ No

    a. If the data contains identifying details, please answer here: (1) What step will you take to ensure the confidentiality of the information? (2) How will the data be stored? (3) What will be done with identifying information or recording of the subjects at the end of the research? the data will be encoded and will be deleted after the research.

VIII. Withdrawal from the Study:

16. Will subjects be informed that they may withdraw from the study at any time? ■ Yes / ☐ No

17. Will the subjects' compensation for participation be affected if they withdraw from the study before its completion? ☐ Yes / ■ No

    a. If yes, are they informed of this fact in the informed consent form? ☐ Yes / ☐ No

IX. Research Equipment

18. Does the research entail the use of equipment other than standard equipment, such as computers, video recording equipment? ■ Yes / ☐ No
19. If yes, does the equipment being used meet safety standard for use with human subjects?

■ Yes / ☐

No

Please specify which standards (include documentation where appropriate): The robot which will be used in the study is programmed to avoid collision and to slow down when aproaching any obstacle. Number Safety Standart - EN 60335-1:2012., EN 60335-2-2:2010 + A1:2012.

Signatories:

Name: Yael

Position:

Signature: Yael Edan **Date**:01.01.2021

Name: Vardit

Position:

Signature: **Date**: 01.01.2021

Explanation form for the participants

<u>נושא המחקר: אינטראקציית אדם-רובוט</u>

*גוף השאלון מנוסח בלשון זכר מטעמי נוחות והינו מכוון לשני המינים.

מטרת העל של הפרויקט הינה למצוא אילו מאפיינים בהתנהגות הרובוט עלולים להשפיע על האינטראקציה בין האדם לרובוט, כאשר הוא מסייע לו בביצוע משימת סיור בסביבה ביתית.

השלב הנוכחי של המחקר נערך בשיתוף פעולה עם מרכזי יום לאוכלוסיית הגיל השלישי ובבניין 90 חדר 8 באוניברסיטת בן גוריון עם גיוס סטודנטים מהאוניברסיטה. המחקר עוסק בגורמים המשפיעים על אינטראקציית אדם-רובוט. משך המחקר כ-45 דק'.

במסגרת המחקר תידרש לבצע משימת סיור ביחד עם הרובוט באמצעות מענה על מספר שאלות שהרובוט ישאל אותך. הרובוט יתחיל בסיור בסביבת הניסוי המורכבת משלושה חדרים. בכל פעם שיכנס לחדר מסוים תצטרך לזהות את האות הנמצאת באותו חדר. לאחר שעבר בכל החדרים יהיה עלייך להרכיב מילה מרצף האותיות אותם ראית לאורך הניסוי. הניסוי יבוצע ארבע פעמים כאשר בכל פעם יתנהג הרובוט בצורה שונה. המערכת מורכבת מרובוט נייד וממשק מסך המוצג לך במחשב. באמצעות מצלמה המותקנת על הרובוט תוכל לראות את הסביבה בצג המחשב.

בתחילת הניסוי תתבקש לענות על שאלון מקדים. לאחר מכן יתבצעו ארבעה תרחישים שונים בהם הרובוט יבצע את משימת הסיור, כאשר בסיום כל תרחיש תתבקש לענות על שאלון שישקף את תחושותיך מהתרחיש הנוכחי. בסיום ארבעת התרחישים תידרש לענות על שאלון מסכם.

בנוסף, במהלך הניסוי תתבקש לענוד שעון למדידת דופק לב שמטרתו לבדוק האם חל שינוי בדופק הלב בין התרחישים השונים.

לא מתבצעת שמירה של הפרטים המזהים של הנבדקים. כל נבדק מקבל מספר נבדק אשר מופרד מפרטי הנבדק. כל השאלונים יימסרו בתום המחקר לחוקרת הראשית הממונה על המחקר וישמרו באחריותה.

אם מכל סיבה שהיא הנך חש שלא בנוח, בבקשה עצור את הניסוי ועורך הניסויים ייגש אליך באופן מידי. בכל עת ובכל שלב תוכל, אם תרצה, להפסיק את השתתפותך במחקר. במידה ורצונך כי הניסוי ייפסק, תשוחרר מהניסוי ללא התחייבות.

פרטים ליצירת קשר עם החוקר:

<u>שם:</u> אלירן יצחק

<u>נייד:</u> 053-831-1132

<u>כתובת מייל:</u> eliranit@post.bgu.ac.il

Consent form for the participants

<u>נושא המחקר: אינטראקציית אדם-רובוט</u>

נבדק יקר,

בבקשה קרא את דף ההסבר באשר לניסוי. במידה ויש שאלות, נשמח לענות.

בבקשה וודא כי הנך מבין היטב את שלבי המחקר.

להזכירך, המחקר עוסק בגורמים המשפיעים על האינטראקציה בין האדם לרובוט. במהלך הניסוי תידרש לבצע משימה סיור משותפת ביחד עם הרובוט. משך הניסוי לכל היותר שעה.

אני החתום מטה*:

שם פרטי ומשפחה:	ת.ז.
חתימה:	טלפון:

1. מצהיר/ה בזאת כי אני מסכים/ה להשתתף בניסוי, כמפורט במסמך המפרט את חלקי הניסוי.
2. מצהיר שהוסברו לי בפירוט כל חלקי הניסויי והסכמתי ליטול בו חלק לאחר שנענו כל שאלותיי לגבי כל אחד מחלקי הניסוי.
3. מצהיר בזאת כי הוסבר לי על-ידי החוקר/ת: ___________________

1) כי אני חופשי לבחור שלא להשתתף בניסוי וכי אני חופשי להפסיק בכל עת את השתתפותי בניסוי מכל סיבה שהיא.

2) במידה ואני חש ברע או באי נוחות במהלך הניסוי חובה עלי לדווח לנסיין על מנת להפסיק את הניסוי.

3) מובטח שזהותי האישית תשמר סודית על-ידי כל העוסקים והמעורבים במחקר ולא תפורסם בכל פרסום כולל בפרסומים מדעיים.

4) כי בחלוף 5 ימי עסקים מיום הניסוי, תהיה באפשרותי לבקש להפסיק השתתפותי במחקר וכל הנתונים אודותיי יימחקו.

5) כי באפשרותי לבקש, ששבוע ימים לאחר תום הניסוי, לצפות בנתונים שנאספו לגביי בניסוי.

6) מובטחת לי נכונות לענות לשאלות שיועלו על-ידי.

7) במהלך הניסוי החוקרים יצלמו תמונות וסרטונים לצורכי מחקר בלבד. במידה ואתה מאשר\ת זאת, חתום כאן:_______________

במידה ואת\ה מסכימים שתמונתכם תופיע בפרסומים שונים שיוצגו לציבור אנא ציינו.

☐ אני מסכים שתמונתי תופיע בפרסומים שונים

☐ איני מעוניין שתמונתי תופיע

8) במידה וייערך ניסוי המשך, האם תהיה מעוניין להשתתף בו? כן / לא
(במידה ותאשר, נפנה אלייך בהמשך)

* הצהרה זו הינה סודית ואינה ניתנת להעברה או שימוש לצורך שום דבר או גורם אחר פרט לצורכי מחקר זה.

תאריך ____________________ חתימת מעביר הניסוי ________________

אנו מודים לך על השתתפותך במחקר.

Preliminary Questionnaire

מספר נבדק *

התשובה שלך

הבא

ניקוי הטופס

שאלון דמוגרפי

גיל *

התשובה שלך

מגדר *

- זכר
- נקבה

השכלה *

- תיכונית
- הנדסאי
- תואר ראשון
- תואר שני
- תואר שלישי
- אחר:

Technology Adoption Propensity questionnaire (TAP)

אנא ציין את מידת הסכמתך עם האמירות הבאות, כאשר:
1 - מאוד לא מסכים
2 - לא מסכים
3 - ניטרלי
4 - מסכים
5 - מסכים לחלוטין

1. אני מצליח ללמוד להשתמש במוצרי ושירותי היי-טק חדשים ללא עזרה מאחרים *

	1	2	3	4	5	
מאוד לא מסכים	○	○	○	○	○	מסכים לחלוטין

2. נדמה לי שאני נתקל בפחות בעיות בהפעלת טכנולוגיה מאשר אנשים אחרים *

	1	2	3	4	5	
מאוד לא מסכים	○	○	○	○	○	מסכים לחלוטין

3. אנשים אחרים באים אליי לקבלת ייעוץ על טכנולוגיות חדשות *

	1	2	3	4	5	
מאוד לא מסכים	○	○	○	○	○	מסכים לחלוטין

4. אני נהנה ללמוד להשתמש בטכנולוגיות חדשות *

	1	2	3	4	5	
מאוד לא מסכים	○	○	○	○	○	מסכים לחלוטין

Negative Attitude toward Robots Scale (NARS)

אנא ציין את מידת הסכמתך עם האמירות הבאות, כאשר:
1 - מאוד לא מסכים
2 - לא מסכים
3 - ניטרלי
4 - מסכים
5 - מסכים לחלוטין

1. הייתי מרגיש לא בנוח אם היה ניתן לי תפקיד בו הייתי צריך להשתמש ברובוטים *

	1	2	3	4	5	
מאוד לא מסכים	○	○	○	○	○	מסכים לחלוטין

2. למילה "רובוט" אין משמעות עבורי *

	1	2	3	4	5	
מאוד לא מסכים	○	○	○	○	○	מסכים לחלוטין

3. הייתי מרגיש לחוץ אם הייתי צריך להפעיל רובוט ליד אנשים אחרים *

	1	2	3	4	5	
מאוד לא מסכים	○	○	○	○	○	מסכים לחלוטין

4. אני לא אוהב את הרעיון שרובוטים או אינטליגנציות מלאכותיות היו מפעילים שיקול דעת לגבי דברים *

	1	2	3	4	5	
מאוד לא מסכים	○	○	○	○	○	מסכים לחלוטין

5. הייתי מרגיש מאוד מתוח רק מלעמוד לפני רובוט *

	1	2	3	4	5	
מאוד לא מסכים	○	○	○	○	○	מסכים לחלוטין

Post trail questionnaire

מספר נבדק

התשובה שלך

איך אתה מרגיש ביחס לאינטראקציה עם הרובוט

אנא ציין את מידת הסכמתך עם האמירות הבאות, כאשר:
1 - מאוד לא מסכים
2 - לא מסכים
3 - ניטרלי
4 - מסכים
5 - מסכים לחלוטין

סוג התרחיש

- ימין
- ימין אמצעי
- שמאל אמצעי
- שמאל

1. האינטראקציה עם הרובוט הייתה חוויה נעימה ומספקת *

	1	2	3	4	5	
מאוד לא מסכים	○	○	○	○	○	מסכים לחלוטין

2. הרובוט היה אמין *

	1	2	3	4	5	
מאוד לא מסכים	○	○	○	○	○	מסכים לחלוטין

3. הבנתי את המידע שהרובוט הציג בפני *

	1	2	3	4	5	
מאוד לא מסכים	○	○	○	○	○	מסכים לחלוטין

4. היה כיף לעבוד בשיתוף פעולה עם הרובוט *

	1	2	3	4	5	
מאוד לא מסכים	○	○	○	○	○	מסכים לחלוטין

5. הייתי מרוצה מהחוויה של אינטראקציה עם הרובוט להשלמת המשימות *

	1	2	3	4	5	
מאוד לא מסכים	○	○	○	○	○	מסכים לחלוטין

6. אני יכול לסמוך על המידע שמספק הרובוט *

	1	2	3	4	5	
מאוד לא מסכים	○	○	○	○	○	מסכים לחלוטין

7. האינטראקציה עם הרובוט הייתה מהנה *

	1	2	3	4	5	
מאוד לא מסכים	○	○	○	○	○	מסכים לחלוטין

8. הבנתי מה שהרובוט עושה *

	1	2	3	4	5	
מאוד לא מסכים	○	○	○	○	○	מסכים לחלוטין

9.מה היית משפר בפעולות הרובוט או באינטראקציה?

התשובה שלך

שליחה

ניקוי הטופס

Final questionnaire

מספר נבדק *

התשובה שלך

1. האם הרגשת בהבדלים בין התרחישים? *

- כן
- לא

אם כן, מה היה ההבדל?

התשובה שלך

2. באיזה תרחיש הכי נהנית? *

- ימין
- ימין אמצע
- שמאל אמצע
- שמאל

3. באיזה תרחיש הרגשת הכי בטוח שתצליח במשימה? *

- ימין
- ימין אמצע
- שמאל אמצע
- שמאל

4. באיזה תרחיש היית הכי מרוצה? *

- ימין
- ימין אמצע
- שמאל אמצע
- שמאל

5. איזה תרחיש עדיף לביצוע משימה זו? *

- ימין
- ימין אמצע
- שמאל אמצע
- שמאל

6. איזה תרחיש הכי פחות עדיף לביצוע משימה זו? *

- ימין
- ימין אמצע
- שמאל אמצע
- שמאל

7. באיזה תרחיש היית אומר/ת שהרובוט היה הכי מנומס? *

- ימין
- ימין אמצע
- שמאל אמצע
- שמאל

8. באיזה תרחיש היית אומר/ת שהרובוט היה הכי פחות מנומס? *

- ימין
- ימין אמצע
- שמאל אמצע
- שמאל

אוניברסיטת בן גוריון בנגב

הפקולטה למדעי ההנדסה

המחלקה להנדסת תעשייה וניהול

פיתוח רובוטים מנומסים והערכה בתרחישים בעולם האמיתי

מאת: אלירן יצחק

מנחה/ים: פרופ' יעל אידן ופרופ' נעם טרקטינסקי

חתימת המחבר: ______ תאריך: 03.06.2022

אישור המנחה: ______ תאריך: 03.06.2022

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אישור יו"ר ועדת תואר שני מחלקתית: ______ תאריך: 6/3/2022

מרץ 2022

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מרץ 2022