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Impact of Robot Size and Number on Human–Robot Persuasion

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Abstract: Technological progress has seamlessly integrated digital assistants into our everyday lives, sparking an interest in social robots that communicate through both verbal and non-verbal means. The potential of these robots to influence human behaviour and attitudes holds significant implications for fields such as healthcare, marketing, and promoting sustainability. This study investigates how the design and behavioural aspects of social robots affect their ability to persuade, drawing on principles from human interaction to enhance the quality of human–robot interactions. Conducted in three stages, the experiments involved 73 participants, offering a comprehensive view of human responses to robotic persuasion. Surprisingly, the findings reveal that individuals tend to be more receptive to a single robot than to groups of robots. Nao was identified as more effective and capable of persuasion than Pepper. This study shows that successful persuasion by robots depends on social influence, the robot's appearance, and people's past experiences with technology.

Keywords: persuasive robotics; social robots; human–robot interaction; persuasion

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1. Introduction

Technological advancements have transformed the world considerably and altered the ways in which humans live and function. Artificial entities, such as Google Assistant and Amazon Alexa, have become significant parts of everyday life. With the rise in Robotic Sciences and its focus on values pertaining to "human-oriented" design, a large body of work has explored physical embodiment integrated into artificial entities and their interactive abilities via proxemics, kinesics, or multisensory stimulation [1]. This led to the concept and reality of social robots. Social robots communicate with humans using both verbal and non-verbal cues, and the human–robot interaction (HRI) literature states that humans are equally as sensitive to the social dynamics present between people and robots as they are to those between people [2]. Scholars have implemented human–human interaction (HHI) models as a basis for designing human–robot interactions to be able to analyse social robot capabilities [3,4]. A recent trend in the field of social robotics is the emergence of 'Persuasive Robotics', which refers to studying persuasion in HRI [5].

It is important to understand the role of robots as persuasive agents to support attitudinal/behavioural change in humans [6] because they are increasingly being used in a large number of applications, such as in health environments, in marketing, or to promote healthy living and sustainability [7,8]. Experimental studies have focused on social robot design and the behavioural factors that influence persuasive capabilities within a given context [9]. In addition to the use of early theories within human–technology interaction to initiate greater compliance [10], current research trends have principally explored theory-based persuasion to understand the impact of robot personality [11], investigate contextual factors [9], and implement HHI persuasive strategies [12].

Even though research within the domain of persuasive robotics has actively attempted to decipher the factors through which persuasion can be achieved, there is limited literature shedding light on the embodiment factors of robots such as 'size' and 'number'. Most research in HRI is based on dyadic interactions [13]. For example, research in health marketing has used only one robot to deliver a message [14]. A review of the literature in this area shows there is a clear lack of empirical research that utilises multiple robots to deliver a persuasive message.

Other studies have explored robot size using subjective perceptions towards the different-sized robots [9]. Several studies that have explored size differences between robots used telepresence bots [15]. Scholars have largely ignored how the size of humanoid robots plays a role in their persuasiveness [16].

The literature reveals that gender has a profound impact on perceptions [17]. Previous studies have looked at how males and females interact with robots. The results show that males were more positive towards the robot compared to females [18]. However, after reviewing the persuasive robotics literature, it is clear that these studies have not explored other key variables of persuasion, e.g., the impact of gender on behavioural change.

This research will attempt to fulfil the research gaps highlighted above by exploring how robot size, robot number, and human gender impact persuasion attempts. Specifically, this study will discuss and compare the influence on persuasion attempts using one vs. two robot(s) and small vs. large robot(s) (Nao vs. Pepper, respectively) between males and females. The following research questions will be addressed:

RQ1: Does the number of robots influence perceived persuasion and compliance?

RQ2: Does robot size influence perceived persuasion and compliance?

RQ3: Does human gender have an impact on perceived persuasion and compliance?

Finally, this study contributes the following aspects:

1. It bridges the gap between the fields of persuasive robotics, human–robot interaction (HRI), and human–human interaction (HHI) through exploring HHI theories of message reinforcement in a persuasive context involving robots and humans.
2. It contributes to the theoretical understanding of the influence of embodiment factors, robot size, and robot number on human perceptions and behavioural change.
3. It helps us to understand gender stereotyping in HRI within a persuasive context when using genderless robots.
4. It provides practical insights into designing effective persuasive HRI where robots need to directly communicate with humans, such as in marketing or promoting behavioural change.

The following sections are organised as follows. Section 2 presents a comprehensive literature review that sets the backdrop for the study, followed by the research methodology being explained in Section 3. Section 4 provides insights into the data collected, their analysis, and the findings generated. This is followed by Section 5, where the results are discussed based on both quantitative and qualitative data. Finally, Section 6 concludes the paper by reflecting on the research limitations and providing research directions for future work.

2. Literature Review

2.1. Social Robots

Social robots interact as peers or companions with humans and fall into the category of 'proximate interaction', where both parties are co-located. The interaction involves social, cognitive, and emotive aspects. The social capabilities of a robot are understood based on two dimensions [19]: the depth of the robot's actual social cognition mechanism and the human's perception of the robot's social aptitude. Familiarity with a robot's morphology influences its desirability, since it influences human expectations about the robot's behaviour and mental state [20]. Fong and others [21] stated four broad categories of robots in terms of being socially embodied: functional, caricatured, zoomorphic, and anthropomorphic. Functional robots appear machine-like and are designed to ensure that their physical features are guided by operational objectives. Caricatured robots appear unrealistic, and their non-humanoid features portray exaggerated versions of simple human motions and emotions. Zoomorphic robots resemble living creatures like cats or dogs and imitate embodiments required to establish potential feelings of companionship. Anthropomorphic robots employ a basic integration of "humanness" in their behaviour and work in a social environment, which helps facilitate interactions, as it utilises underlying principles and expectations that humans use in a social setting [22]. Anthropomorphism influences human tendencies to trust and empathise [23].

This research uses two popular humanoid robots developed by Aldebaran SoftBank Robotics (joint company, Softbank, Tokyo, Japan; Aldebaran, Paris, French): Pepper (NAOqi 2.5) and NAO (v5). These robots are suitable for the current research due to their multimodal expressive gestures, gender-neutral aspects that avoid stereotyping, and their overall appearance not crossing the "Uncanny Valley"—where people reject an object 'too realistic and comparable to human but that which is not similarly accurate' [24].

2.2. Persuasive Social Robotics

2.2.1. Persuasion in Human–Human Interaction

Persuasion is defined as "human communication designed to influence the autonomous judgements and actions of others", where attitude is one of the key concepts that will dictate the sequence of actions for a person [25]. There are numerous theoretical advancements that provide an overview of the processes that take place during the act of persuasion. For instance, the Elaboration Likelihood Model (ELM) focuses on aspects of attitude change via two routes—central and peripheral [26]. The central route is logic-based, while the peripheral route is based on extrinsic factors like social cues (e.g., attractiveness and likeability) related to the message source. The route chosen is dependent on the receiver-side motivation to elaborate on the persuasive message, collectively known as the elaboration level. Two of the key peripheral cues are likeability and credibility [27]. Furthermore, the expertise and trustworthiness of a source are significantly related to message effectiveness [28], as information credibility is proportional to source credibility [29]: a more credible source is more likely to be believed and accepted [30].

2.2.2. Persuasion in Human–Computer Interaction

Persuasive technology is technology that alters human behaviour, and it has been the focus of sustainable Human–Computer Interaction (HCI) for years, meaning that computers can persuade and influence sustainable behaviour in humans via interactive computing such as mobile applications, social media, interactive displays, and persuasive games [31]. Persuasive technology can be used as a persuasive agent to form, alter, or reinforce (a) attitudes, (b) behaviour, or (c) acts of compliance. Researchers have implemented persuasion strategies such as computer-mediated reminders to promote healthy water intake [32], tested the potential of a mobile application to assist in the prevention of adolescent weight gain issues [33], worked with a pedagogical agent to maximise the effectiveness of instructions [34], worked with a virtual avatar expressing feedback through emotions to enhance work health safety [35], and designed an intelligent agent, iParrot, to persuade users to conserve energy [36]. It has been seen that most studies within persuasive technology have the positive psychological outcomes of encouragement and greater engagement and motivation via persuasion [31]. With positive progress, the research focus has shifted from persuasion in HCI to HRI.

2.2.3. Persuasion in Human–Robot Interaction

HRI is largely different from HHI and HCI, as even though there are social robots, it is the human's perceptions of these robots that influence behavioural or attitudinal change for individuals [9]. This difference calls for a greater investigation into persuasive scenarios in HRI. Many of the human–human social rules are applicable to HRI, such as stereotypes [37], social framing [38], and human–robot trust models [39]. Human–robot persuasion has been a topic of interest for a while, and scholars [5] have discovered that persuasion is an inseparable component of HRI, like HHI.

Persuasive robotics is described as "the scientific study of artificial, embodied agents (robots) that are intentionally designed to change a person's behaviour, attitudes, and/or cognitive processes" [40]. Research on persuasive robotics has reported appearance, communication style, and implemented gestures as some of the factors that influence the persuasive capabilities of robots [41]. More recently, scholars have discovered a diverse range of persuasive factors and grouped them under five categories: Modality (robot presence), Interaction (interactive functionalities), Social Character (human/non-human character traits), Persuasive Strategy, and Context (contextual factors) [9].

2.3. Reinforced Messaging

Persuasion researchers in HHI have observed phenomenon such as 'conformity pressures', which state that mere influence can lead to an attitude movement in a specific direction [42]. Researchers noted that multiple arguments enhance persuasion, as when individuals are confronted with multiple sources expressing multiple arguments, it leads to a more thorough processing of the message [43,44]. Harkins and Petty (1987) further reported that a message was deemed more credible and persuasive when multiple sources were independent and were not initiating persuasion as a combined entity, since this led to a countereffect [45]. Some of the work in HRI has explored the probable positive effects of using multiple messaging techniques/multiple sources even though this was not the main objective of the studies [12,15,46]. Other experiments showcased the benefits of multi-agent persuasion via virtual agents in conjunction with the other dimensions of agent gender, status, and persuasion type [47]. In summary, prior work suggests a positive influence of reinforced messaging/multiple sources on persuasion.

2.4. Robot Size

In HHI contexts, height plays a role in how humans perceive and judge each other. A taller stature is often linked to an individual being more persuasive and self-assured [48]. There is limited work in HRI that investigates the impact of robot size specifically on persuasive capabilities. Most work surrounding persuasive robotics has implemented a mix of various types of robots [9], such as tabletop, humanoid, and telepresence. Robots require social presence (SP) to highlight their company as a social entity, because it stimulates and motivates humans during interaction. Robot size is of paramount importance in conjunction with SP [49]. Hiroi and Ito define robot size as the height of the robot [50]. Torta and colleagues reported a high level of trust and low SP for NAO due to its small size. Other studies [51,52] reported mixed reactions, with a bigger robot being more suitable for social interactions and taller human-like robots deemed as more intelligent than shorter ones. More recent work [53] used virtual reality experimenting to investigate participant compliance, and the results revealed that appearance (anthropomorphism) had larger effect on preference and emotional response than on compliance. Thus, there is a potential for robot size to have an influence on persuasion.

2.5. Gender

While there are existing gender stereotypes in HHI and HCI, studies [41,54–56] in the realm of HRI did not find any significant contrasts between male and female participants in terms of compliance and user acceptance across different age groups when using gender-neutral robots. Nevertheless, during instances where robots were assigned genders, males were greatly persuaded by female-gendered robots and participants rated opposite-gendered robots as more credible and trustworthy [5,57]. In general, human gender has been seen to influence the perception of a robot alongside any gender cues that a robot may display [17]. Since factors related to human gender and context relate to perceptions of robots (regardless of robot gender), it is difficult to provide a solid explanation [58].

2.6. Perceived Persuasion and Competence

Two universal dimensions of 'warmth' and 'competence' can influence the extent to which a trustee is trusted [59]. Trust in HRI has been explored on the basis of the perceived competence of a robot based on anthropomorphism [60] and reliability [61]. Competence is derived from the possession of knowledge, attributes, or skills [62]. Al Mahmud and colleagues tested the perceived competence of their persuasive agent, iParrot, through measures of how knowledgeable, responsible, and intelligent it was perceived as being by individuals [36]. In line with this, another study evaluated the persuasiveness of a mobile application in influencing energy conservation [63]. Perceived persuasion was measured in terms of how competent (perceived competence) and reliable/trustworthy the intended persuasive agent was to the individuals. It is evident that trust is crucial due to its direct correlation with the willingness of humans to comply with robot-generated suggestions [64].

2.7. Research Aims

This research focuses closely on how humans perceive and comply with communication processes involving multiple robots. It assesses whether two robots are better at persuasion through the reinforcement of a target persuasive message. The experiment also analyses the effect of robot size and human gender on persuasion. This study incorporates three conditions set up as a between-subject design, with the first two stages inclusive of single-robot interaction, each with different robot sizes. The third stage includes multi-robot interaction with both robots involved in the interaction process. Therefore, the study proposes the following hypotheses:

Hypotheses 1a–1b, Two robots will be better at persuading humans than a single robot.

H1a: *Two robots have higher perceived persuasiveness than one robot.*

H1b: *Two robots have higher perceived competence than one robot.*

Hypotheses 2a–2b, A larger robot will be better at persuading than a smaller robot.

H2a: *A larger robot has higher perceived persuasiveness than a smaller robot.*

H2b: *A larger robot has higher perceived competence than a smaller robot.*

Hypothesis 3: *Males will perceive the robot's perceived persuasiveness and perceived competence as higher than females.*

3. Materials and Methods

Studies in marketing have used scenarios to test how consumers respond to persuasive advertisements [65]. Kharub and others [14] implemented the same strategy in a social robot context to understand the effectiveness of robot-enacted advertisement messages. By adapting the same methodology, it is important for researchers to understand how the robot's interaction differs in terms of (1) single vs. multiple robots, (2) small vs. large robots, and (3) male vs. female respondents during a persuasive attempt by a robot.

This research adopted an experimental research approach and design, where the dependent variables (perceived persuasion and competence) are derived from the manipulation of the independent variables (number of robots, robot size, and human gender) [66]. The research design performed a 2 (tall vs. short) $\times$ 2 (one vs. two) $\times$ 2 (male vs. female) between-subject experiment at the Western Sydney University campus. The study was divided into three conditional scenarios. There were two types of humanoid robots used, Pepper and Nao, as persuasive agents across the three scenarios. Participants engaged in a persuasive interaction with the robot(s) and answered the online questionnaire, pre- as well as post-interaction. The questionnaire gathered both qualitative and quantitative data; it implemented the 7-point Likert scale for all items that were measured, with items of negative valence on the left and those with positive valence on the right. Ethical requirements were taken into consideration, and ethics approval was obtained before conducting the research (HREC approval #: H15233).

3.1. The Robots

Pepper is a 1.2 m tall wheeled humanoid robot developed by SoftBank Robotics, designed with a wide range of multimodal behaviours and expressive gestures [67]. It was designed carefully to ensure that it does not look overly human to avoid falling into Uncanny Valley and comes equipped with a touch screen, tactile hands, and LEDs to support multimodal interaction. Pepper is gender-neutral, with a child-like androgynous voice. Nao is 0.57m tall and designed to look approachable, resembling a human toddler [68]. NAO has good mobility and can bend forward and sit. Research has found that NAO is perceived as genderless, cute, non-judgmental, neutral, and capable of intervening to influence behaviour change [17,69].

3.1.1. Robot Programming

Both Pepper and Nao were pre-programmed using Python and the NAOqi framework (robot OS) and run on a Mac and Windows laptop to feed data into the robots. A graphical user interface was coded and controlled via the experimental technique of Wizard of Oz (WoZ). ALProxy, a class of objects that provides access to a range of existing modules within the framework, was used to call for the module 'ALAnimatedSpeech' to use its method 'say' and make the robots speak the desired persuasive dialogues via their respective IP and Port.

3.1.2. System Architecture

A router was used to provide the robots with their IP addresses as a DHCP server. Both robots and laptops were connected to the router for seamless control. The scenarios were manipulated, and the input was gathered via coded GUI. The system consisted of two sections, robot behaviour and autonomous life. Robot behaviour is user-manipulated and implements the NAOqi modules to generate the interaction script. Autonomous life during its 'on' state generates default abilities that make the robots 'alive' through reactions like blinking LEDs, face detection/tracking and movement during speech, and listening in response to any stimuli from participants (Figure 1).

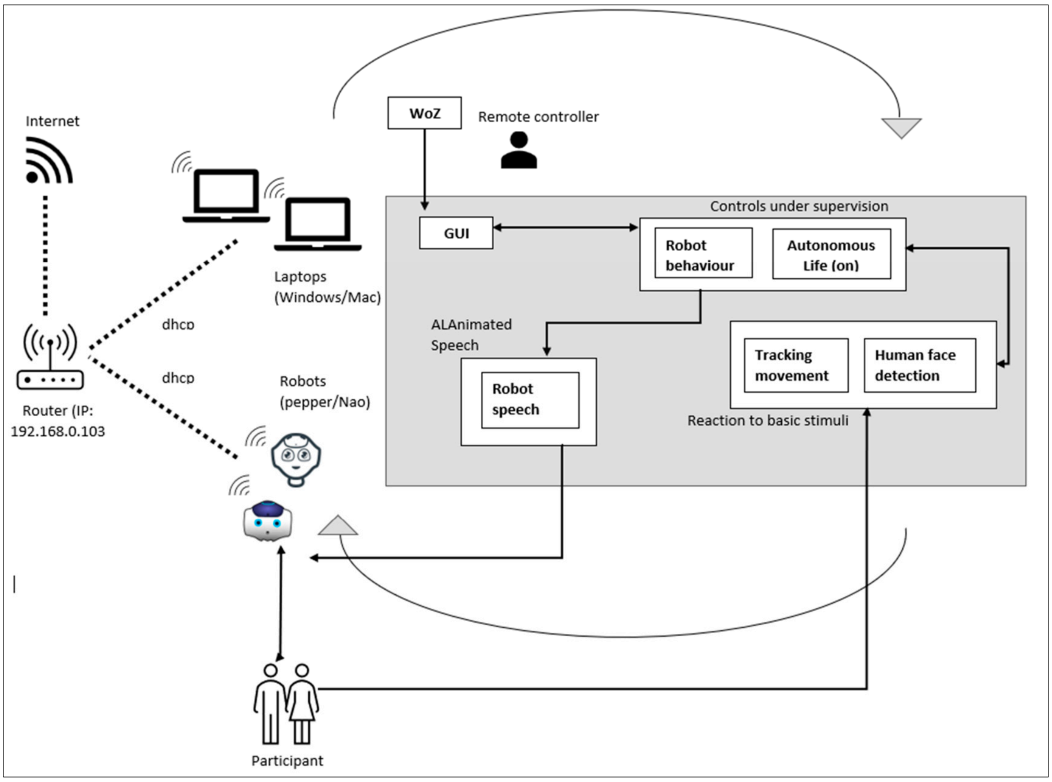

Figure 1. System architecture.

3.2. Research Design

3.2.1. Sampling Process

A proportion of undergraduate students was selected as the target population for this study via convenience sampling. This is in line with prior work in persuasive robotics [70] and ensures less influence from external factors on decision-making for the participants, as the individuals in the chosen sample are potentially at "similar life stages" [14]. There was a total sample size of 73 participants; stage 1 had 30 students, stage 2 had 20 students, and stage 3 had 23 students, which is considered adequate based on prior works [9,36,63].

3.2.2. Data Collection

Energy drink consumption is a public health concern, and most young adults (61.3%) consume the highest number of sugary and caffeinated drinks at least once a week [71]. This was used as a stimulus to design the research scenarios—two fictitious energy drinks were used to test the hypotheses and observe a change in decision among the respondents. Fictitious products were used, so that participants would have no prior attitude towards the drink options presented [72]. Hyped-Up and Energise were the two drink options, each with different nutritional contents (Table 1). The scenarios have been adapted from [14] and altered according to current research settings. A pre-test was conducted in the study by Kharub et al. to see whether scenarios were relevant to respondents and brand names were realistic. The results of that study showed the brands were valid and usable to test consumer's selection of drink options. Thus, the scenarios from Kharub and others were adapted and adopted in this research.

Table 1. Fictitious energy drinks.

Drink Options	Nutrition Contents
Hyped-Up	50 g of sugar and 10 g of caffeine
Energise	10 g of sugar and 50 g of caffeine

Across all scenarios, the robot(s) delivered appropriate persuasive dialogues for Hyped-Up and Energise depending on participant drink selections. For instance, Table 2 shows the dialogue examples for when participants chose the drink option "Hyped-Up".

Table 2. Dialogue examples when participants chose the drink option Hyped-Up.

Experimental Condition	Interaction Dialogues
Stage 1: Pepper	"Hi There! Thank you for making a selection. Before I hand you your drink, let me ask you a question. Did you know that another energy drink Energise has only 10 g of sugar and 50 g of caffeine? That would mean it has less sugar than Hyped-Up and reduces risks of weight gain issues. Would you like to switch your selection?"
Stage 2: Nao	"Hi There! Thank you for making a selection. Before I hand you your drink, let me ask you a question. Did you know that another energy drink Energise has only 10 g of sugar and 50 g of caffeine? That would mean it has less sugar than Hyped-Up and reduces risks of weight gain issues. Would you like to switch your selection?"
Stage 3: Multi-Robot	Pepper: "Hi There! Thank you for making a selection. Before I hand you your drink, let me ask you a question. Did you know that another energy drink Energise has only 10 g of sugar and 50 g of caffeine?" Nao: "That would mean it has less sugar than Hyped-Up and reduces risks of weight gain issues. Would you like to switch your selection?"

The research implemented a Wizard of Oz set-up and followed Green and colleague's method for WoZ HRI scenario construction [73] to design the flow of events for each experimental condition (Figure 2). This is a method widely used by scholars in HRI studies to explore user behaviours [74]. Pre-defined persuasive dialogues (Table 2) for all scenarios were manipulated by the researcher (WoZ) to ensure that there was no delay in the robot's response and the experiment was executed smoothly. This helped control the occasional episodes of the robot's tendency of distractibility by minute noise and/or movement.

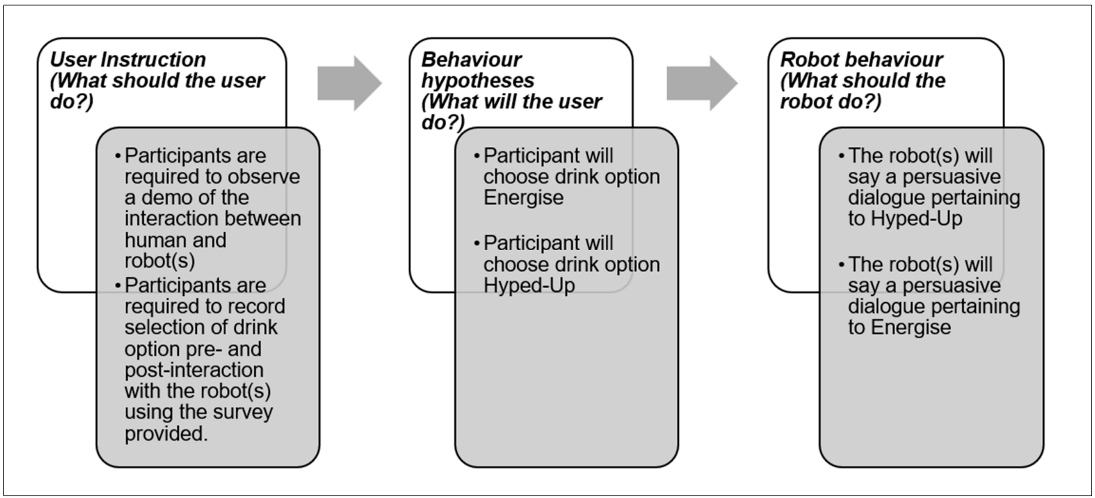

Figure 2. Scenario construction.

3.2.3. Procedure

The recruited participants were provided with information sheets and consent forms (embedded within the survey) to sign, as required by the university ethics committee. The experiments took place in a laboratory/classroom setting, and the room was equipped with computers to collect survey responses. The experiments were conducted with one participant at a time. The robot/robots (depending on individual scenario type) were present in the room throughout the course of the experiment sessions. The procedure undertaken was as follows for all scenarios:

1. Participants were briefed about the procedure and the sequence in which the activity would unfold. They were provided with the live online link to the Qualtrics survey.
2. Participants were then presented with the two drink options and their nutritional value projected on a large screen. They were given sufficient time to read the hypothetical brand descriptors.
3. Participants were then asked to start the survey and read through the provided scenario—"In a hot sunny afternoon and after a long day at the university, you need a pick-me-up drink before next class. While walking, you see an energy drink sample testing happening on campus. The energy drinks are—ENERGISE and HYPED-UP. Now, you will need to choose a drink".
   Based on the scenario, participants were asked to make the initial drink selection.
4. Once the drink was selected, the robot/robots delivered persuasive dialogues depending on the brand selected (refer to Table 2).
5. Immediately following the interaction, participants resumed the survey and recorded responses to the variables of experience with technology, robot characteristics, human perceptions, and clarity and qualitative remarks as open-ended questions
6. Finally, the participants were asked to record their drink selection post-interaction, followed by a few demographic questions (age, gender, employment status, and race). This marked the end of the experiment scenario.

3.2.4. Measures

An online questionnaire was developed using Qualtrics separately for each stage, and the scale implemented was adapted and adopted from credible sources [36,63,75]. The survey included measures for experience with technology, robot characteristics (15 pairs of opposite adjectives to record the impression of the robots during interaction), perceived persuasion (calculated measure using the mean values of four of the robot characteristic items, ignorant–knowledgeable, irresponsible–responsible, unintelligent–intelligent, and unreliable/untrustworthy–reliable/trustworthy), perceived competence (calculated measure using the mean values of three of the robot characteristics items, ignorant–knowledgeable, irresponsible–responsible, and unintelligent–intelligent), drink selections (and post-interaction drink selections), human perceptions (subjective opinions about persuasion and compliance), demographics, and open-ended questions.

4. Results

A snapshot of the respondent profile and their demographic characteristics presented 70% of respondents in stage 1, Pepper, within the age group of 25–34 years, with 53.33% being females and 40% being males; 100% of respondents in stage 2, Nao, were within the age group of 18–24 years, 50% were females, and 45% were males. In stage 3, Pepper and Nao, 95.65% respondents were within the age group of 18–24 years, with a greater weightage of females—60.87%—and 39.13% males. Around 11.66% of participants preferred not to mention their gender. Alpha reliability tests (Table 3) (figure in Section 4.2) were conducted for all three stages to ensure internal consistency and were reported as follows:

Table 3. Alpha reliability test.

Variable	Reliability (Cronbach's Alpha)
Prior experience with technology	0.995
Robot characteristics	0.941
Human perceptions (persuasion/compliance)	0.759
Perceived persuasion	0.873
Perceived competence	0.890

4.1. Hypotheses 1—Robot Number

An analysis of variance was conducted with the number of robots as the first independent variable, and perceived persuasion and perceived competence were the measurements. Comparisons were made between a single robot and multiple robots. The multivariate results showed evidence of a significant main effect for the number of robots (Pillai's Trace = 0.106, F (2, 70) = 4.168, p = 0.019), with a significant influence on both perceived persuasion (F (1,71) = 6.68, p = 0.012) and perceived competence (F (1,71) = 8.07, p = 0.006). The results revealed that interaction with a single robot achieved greater perceived persuasion (M = 5.45, SD = 0.93) and perceived competence (M = 5.62, SD = 0.98) compared to interaction with multiple robots. As a precautionary measure, the analysis was repeated using a non-parametric test (Kruskal–Wallis), and the results demonstrated a statistically significant effect on perceived persuasion (H (1) = 3.77, p = 0.052) and perceived competence (H (1) = 5.42, p = 0.020) between the two groups, with higher mean ranks of 40.25 (persuasion) and 40.88 (competence) for the single-robot group and lower mean ranks of 29.93 (persuasion) and 28.57 (competence) for the multi-robot group. Therefore, hypotheses 1a–1b are rejected, as the results report that a single robot has higher perceived persuasiveness and competence than multiple robots (Figure 3).

4.2. Hypotheses 2—Robot Size

A second analysis of variance was conducted with condition type as the second independent variable, and perceived persuasion and perceived competence were the measurements. Comparisons were made among the three condition types of Pepper, Nao, and multi-robot. The multivariate results showed evidence of a significant main effect for condition type (Pillai's Trace = 0.155, F (4,140) = 2.944, p = 0.023), with a significant influence on both perceived persuasion (F (2, 70) = 4.024, p = 0.022) and perceived competence (F (2,70) = 5.291, p = 0.007). A Bonferroni post hoc test indicated that Nao had significantly higher perceived persuasion (M = 5.68, SD = 0.98)) compared to the condition with multiple robots (M = 4.70, SD = 1.53). For perceived competence, Nao (M = 5.93, SD = 0.99) achieved a significantly higher value compared to the multi-robot condition (M = 4.78, SD = 1.56).

In contrast, there was no significant effect found between Pepper and the conditions of Nao or multiple robots for wither measure. Therefore, hypotheses 2a–2b are rejected, as the results indicate no significant difference between the smaller robot Nao and the larger robot Pepper in terms of perceived persuasiveness and competence (Figure 4).

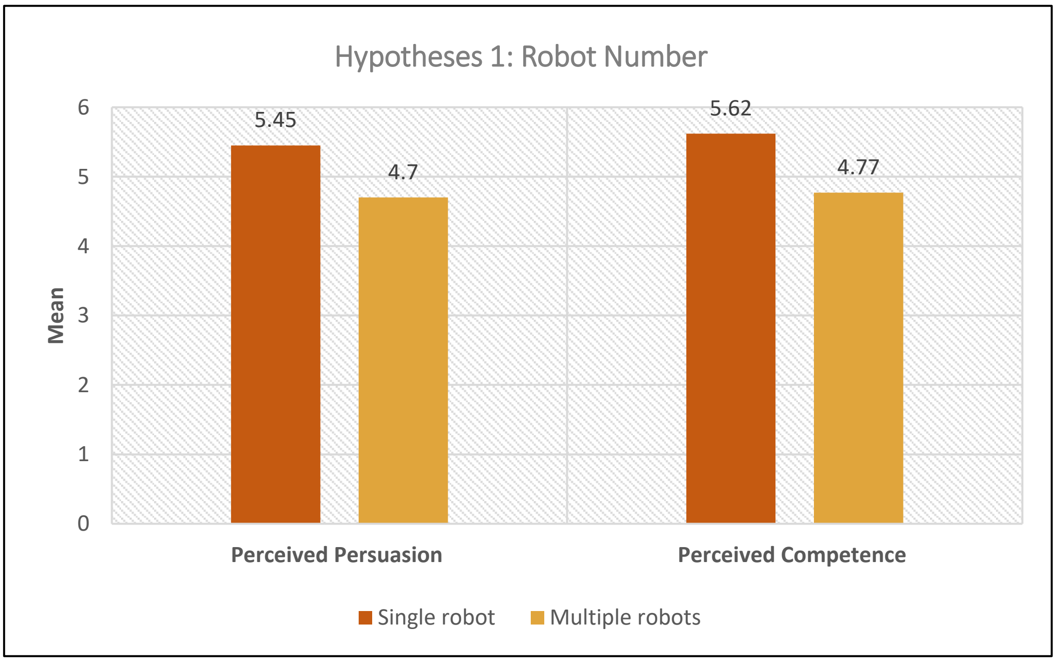

Figure 3. Mean values for perceived persuasion and perceived competence per condition: a single robot vs. multiple robots.

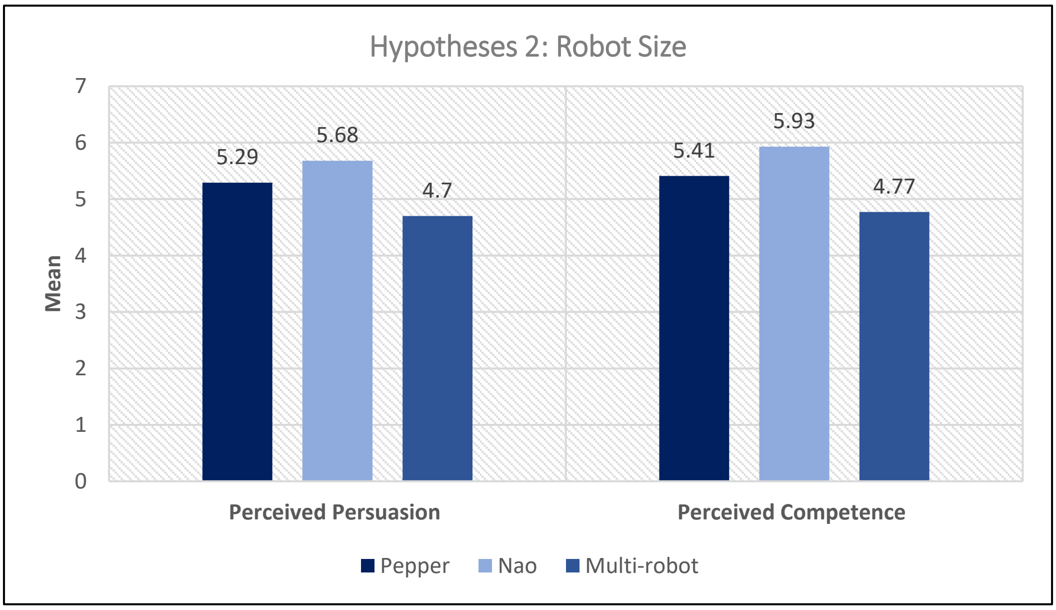

Figure 4. Mean values for perceived persuasion and perceived competence per condition: Pepper vs. Nao vs. multiple robots.

4.3. Hypothesis Hypotheses 3—Gender Effect

A *t*-test comparison was conducted to examine the effect of the third independent variable, gender, on perceived persuasion and perceived competence across all stages. During interaction with Nao, there was a statistically significant effect found on perceived persuasion (t (17) = 1.802, p = 0.045), with males (M = 6.14, SD = 0.72) being more persuaded than females (M = 5.40, SD = 1.02). Similarly, a nearly significant effect on perceived competence was found (t (14.96) = 1.56, p = 0.07), where Nao appeared more competent to males (M = 6.33, SD = 0.69) than females (M = 5.67, SD = 1.14). During interaction with Pepper and the multi-robot scenario, there was no significant effect observed for either measure. Therefore, hypotheses 3 is accepted, as the results show that males did have a significantly higher perceived persuasiveness and marginally significantly higher perceived competence than females, especially during interaction with the small robot (Figure 5).

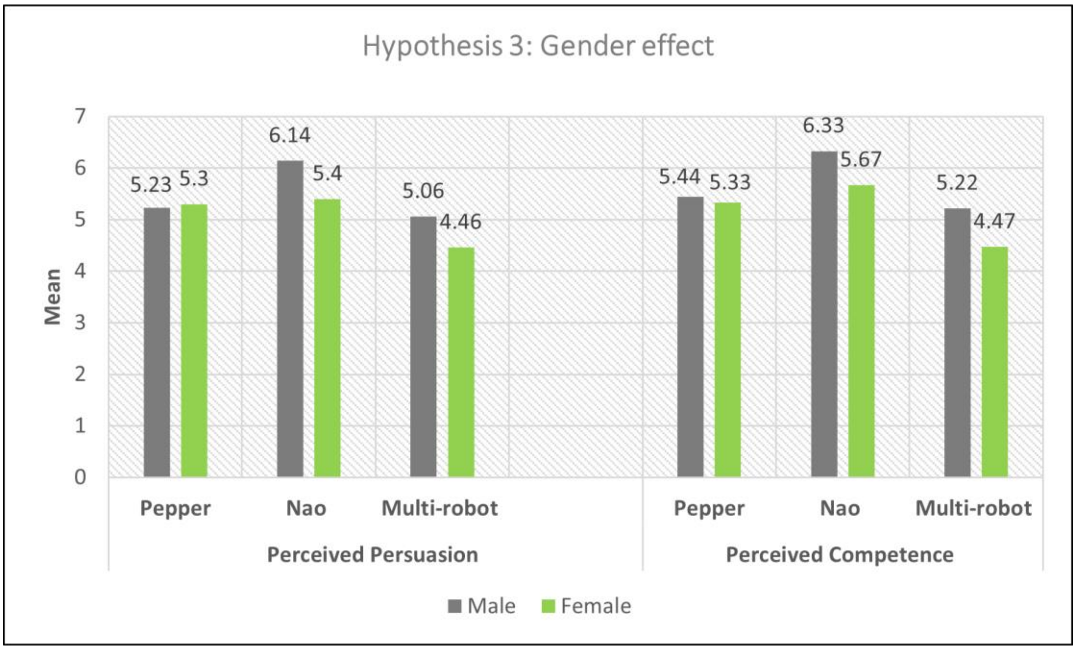

Figure 5. Mean values for perceived persuasion and perceived competence per condition: male vs. female across all stages.

4.4. Qualitative Analysis

Collectively, post-interaction responses showed an 8.22% change in participants' drink selections, which comprised mostly males, with one female, such as in stage 1, Pepper (3 males), stage 2, Nao (1 male), and stage 3, multi-robot (1 male and 1 female). Furthermore, participants in stage 2, Nao, were most familiar with technology, followed by stage 1, Pepper, and stage 3, multi-robot (Figure 6). Participants' subjective opinions on persuasion and compliance were also recorded. It is evident that stage 2 participants found the Nao robot to be most persuasive and expressed the tendency to comply with its advice, followed by Pepper and the multi-robot stage (Figure 7).

Interesting perspectives were brought to light through qualitative remarks, with comments on robot characteristics and aspects relating to accuracy and a knowledgeable attitude. Stage 1: There were positive remarks about Pepper's ability to convey the message promptly and its cheerful tone. The conversation was concise, and the robot was perceived as physically attractive and friendly. Yet, several participants found that the interaction was too short, fast, and not very human or too human-like (uncanny effect). There were higher expectations of Pepper to be more artificially intelligent and to carry on the interaction further. Stage 2: Participants observed Nao to be positively interactive, especially with its arm movements that enhanced its persuasive relay. It was also perceived to be cute, knowledgeable, and with clear fluency, simulating a real-life experience. However, the interaction was marked as too short, and the robot was thought to be unreliable, with an inconvenient height. In contrast to Pepper, it was 'not' human-like, and several students felt that the voice was robotic, making it strange to talk to. Stage 3: Participants found both robots interesting, unique, and factual. They admired the non-verbal interaction cues such as hand gestures and were fascinated by seeing robots for the first time. Nevertheless, the majority of the negative comments circulated around the aspect of the robots being creepy, scary, and freaky and not warm or natural [76]. Participants expected more spontaneity, considering that there were two robots, and they were also more uncomfortable and frightened in comparison to stages 1 and 2. A remarkable gender-related aspect was also observed relevant to our study. Qualitative data revealed that most males referred to the robots (both Pepper and Nao) across all stages as "she" and therefore perceived them as female-gendered. Similarly, one of the female participants referred to Nao as "he" and perceived it as male-gendered.

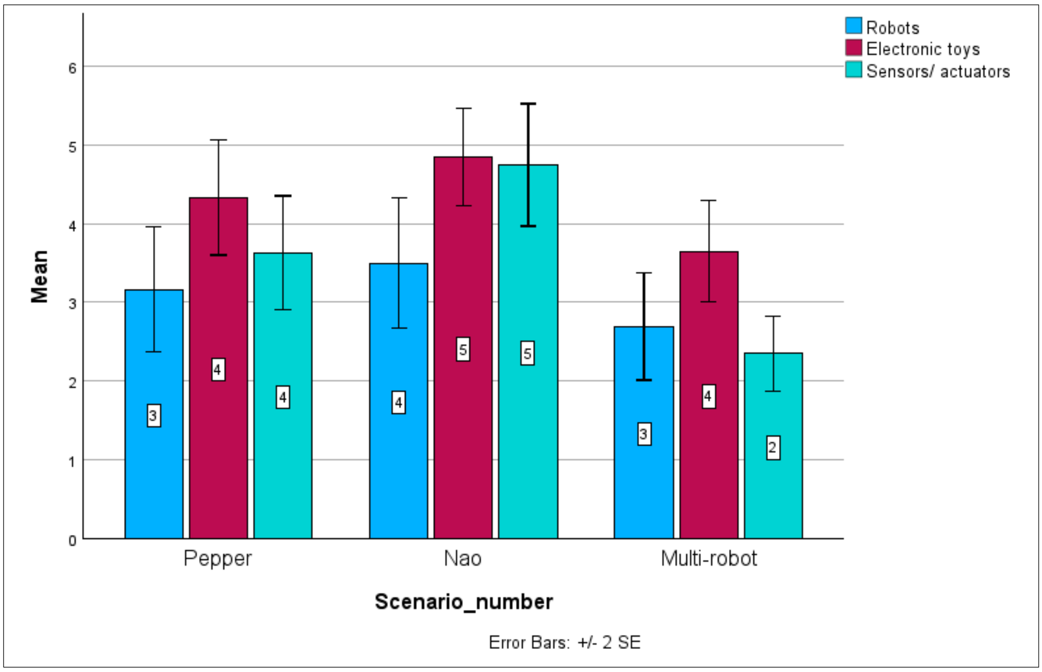

Figure 6. Familiarity with technology (error bars displaying standard error — multiplier 2).

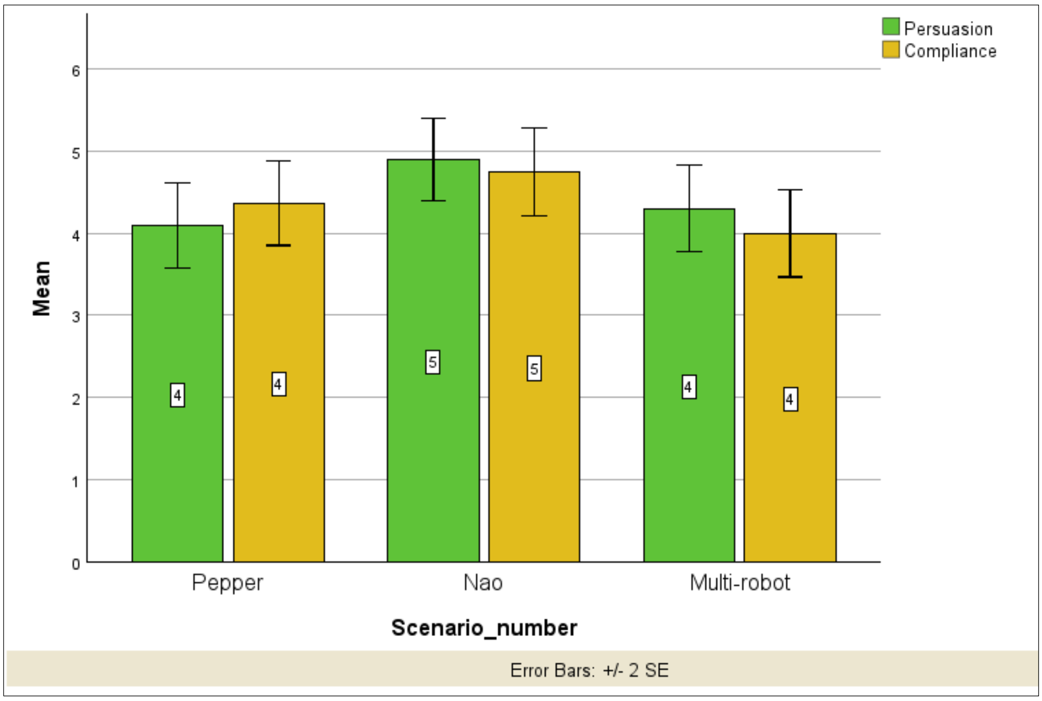

Figure 7. Subjective persuasion (error bars displaying standard error — multiplier 2).

5. Discussion

The quantitative results reveal that single robots are better than multiple robots at persuading humans and gaining compliance. This is surprising, as previous works [12] have reported otherwise. Furthermore, a breakdown of the results showed that NAO was perceived to be most persuasive and competent compared to both the Pepper and multi-robot scenarios. The participants' subjective opinions regarding persuasion and compliance also aligned with these results. These outcomes may be categorised as (1) the impact of social influence and robot morphology, (2) the effect of prior experience with technology, (3) intergroup dynamics, and (4) social rapport and the duration of the interaction [77].

In HRI, the human tendency to assign inanimate objects with human-like attributes plays a key role in acceptance and facilitation of interaction. However, the Uncanny Valley effect could cause uneasiness [24]. Previous studies have reported participants feeling eerie/creepy responses that are specific to physical attributes like eyes during interaction with Pepper [76]. Pepper is more anthropomorphic [67], while Nao is more childlike and cute [78]. A robot that looks like a baby is likely to gain more compliance when it is giving advice [79]. Rosenthal and Kramer also pointed out that design features like a bipedal form could influence human-like attributions and perceived likability [80]. The results from this study clearly show participants found Pepper more human-like and thus had greater expectations. Yet, this aspect may have been overlooked during interaction with Nao for obvious reasons. With two robots in the frame, it is evident that expectations would be high, as suggested by the qualitative remarks discussed. Closely related to anthropomorphism is the underlying factor of social influence, where a greater degree of anthropomorphism relates to higher social influence due to greater social presence [78]. It could be inferred that Nao was perceived to be more competent, lifelike, and socially present, projecting greater social influence, which resulted in higher perceived persuasiveness compared to the other groups.

Familiarity significantly impacts a robot's trustworthiness and persuasiveness [54]. There is greater willingness to interact with a robot when participants have exposure, e.g., have watched a movie with a humanoid robot in it. Additionally, there are lower levels of fear/anxiety when humans are exposed to media portrayals of robots in a positive setting [81]. Since the multi-robot group had the lowest experience with technology, and specifically low familiarity with robots, there could be an impact on the participant's perception of the robots.

Intergroup dynamics, as reported by prior work [82], suggests that humans tend to self-categorise when subjected to outgroups with increasing perceived threat/competition. So, the coordinated behaviours of the robots relate to greater intergroup competition causing humans to develop a negative attitude/emotion towards them [83]. Thus, in the multi-robot scenario, participants may have perceived the robot group as teaming up against them, or more intelligent, resulting in fear and discomfort. Alternatively, with single robots, intergroup competition is potentially seen as lower.

An absence of connection could potentially nullify robots' authoritative status, which is positively correlated with obedience [84]. In the context of our study, there was no opportunity/setting for humans and robots to develop any form of social rapport or relationship, primarily due to the noticeably short duration of the interaction. This is acknowledged by couple of participants, who stated that the interaction was not "warm, inviting or natural" or "it didn't go long enough to have a clear judgement". Even though this was the case across all groups, expectations from the multi-robot group were presumably high.

The study results found that robot size does not appear to influence persuasion and compliance. As mentioned, current studies have a mixed take on this concept and argue that it rather has a psychological effect on humans [50]. Certain findings suggest that lower-height robots are more comfortable to interact with, while others suggest that a taller height is preferable, as humans do not have to bend down for interaction. This was also observed in the qualitative comments for Nao in our study; the robot height was 'inconvenient', and there were remarks asking to make it 'bigger'. On another note, research states that a shorter robot is perceived to be friendlier [85], such as Nao. Robot height does not have a direct impact on preference as much as robot appearance, since height plays a role in the overall perception of the robot [52].

The results also revealed that males had a higher perceived persuasiveness and competence, confirming that there is a gender effect present. Previous work in HCI and HRI support this phenomenon; males complied with a persuasive agent more readily and had a more positive outlook on robots in general [36,58]. However, it is interesting to note the robots used in the current study were 'gender-neutral', and past research has mentioned no differences in perception between male and female participants when robot gender markers are removed or non-existent [41,56]. However, more recently, researchers [86] have come to a consensus that humanoids are likely to be attributed as either male or female based on their social human-like cues, despite being genderless. They mention that it is difficult for humans to speak to entities with no pre-defined gender, and so humans subconsciously ascribe one. Our study monitored such behaviours, where males referred to both Pepper and Nao as "she", and females referred to the robots as "he," with just one female making an opposite reference. This is a novel finding that suggests that humans tend to prescribe genderless robots with characteristics of the opposite gender during an interaction. This postulates the popular cross-gender effect, as seen in the works [5,57], where males rate opposite-gendered robots as trustworthy and more credible.

Based on the study findings, HRI practitioners can leverage the use of persuasive social robots effectively in various contexts, for instance,

1. To create a sales pitch for gender-specific products such as male cologne, a female-gendered robot may prove to be most effective;
2. Single robots should be used to promote healthy behavioural changes in health marketing;
3. Robot interaction will need to be considered accordingly, based on the dominant gender group present for an intended product.

6. Limitations and Future Research Directions

Despite interesting discoveries, there are several limitations to consider due to the exploratory nature of this study. It was limited to a university setting and a short one-off interaction. A novel effect could have been present, and equally, there could be instances of a Hawthorne effect. The generalizability of results is also confined to the younger population. Furthermore, this research is limited to robots with no gender.

Future work should consider a distinct set of demographics and conduct a longitudinal study to eradicate the novelty effect and facilitate the development of social rapport between robots and humans to gather more defined results. In addition, future work should extend on this research by exploring the impact on the perceived persuasiveness and competence of robots with genders.

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