# Improving Human-Robot Interaction: Modifications of a Social Robot on Dimensions of Gender and Personality

By

Daniella Massa

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**Abstract**

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Previous research in Human-Robot Interaction (HRI) has shown that social female robots typically evoke more cognitive and affective trust. Studies also show that extroverted robot personalities are associated with desirable social outcomes. In this experiment, I tested the extent to which a robot's gender (male vs. female) and personality (introverted vs. extroverted) impact the success of a given human-robot interaction. Specifically, I evaluated if the gender of a robot has an effect on the human preference for extroverted personalities. Prior to interacting with a robot, participants completed a baseline Negative Attitudes Towards Robots Scale [9]. Then, during the interaction, the robot asked the participant a variety of questions in an interview-like manner. After this dialogue concluded, the robot requested the participant to execute a task, which was used as a behavioral measure. Once the participants were done with the task, they completed two self-report measures: a Robot Comfort Scale [9] and a Robot Reaction Scale [7]. Results showed that participants felt more comfortable interacting with the extroverted female robot compared to the introverted female robot. However, the opposite was true for the male robot: participants felt more comfortable interacting with the introverted male robot compared to the extroverted male robot. Furthermore, participants tended to have better general reactions to the extroverted female robot compared to the introverted male robot. This study demonstrates that the notion of extroverted robots yielding desirable social outcomes is not generalizable on dimensions of gender.

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# 1 Introduction

The field of social robotics consists of designing a robot that has the ability to follow implicit social rules and mimic human behavior [1]. Similarly, Human-Robot Interaction (HRI) involves monitoring how humans respond to interacting with a social robot [3]. Both of these fields are prominent areas for modern research in computer science. With the expansion of social robotics and HRI research, robotic agents are now being implemented in a variety of real-world settings: classrooms, business industries, restaurants, etc. [2][5][10]. However, in order for these robotic agents to work effectively within a given environment, it is imperative that they are designed in such a fashion that generates desirable social outcomes. In other words, it is essential to discover which factors mediate a successful interaction between a human and a robot.

Although previous research has begun to analyze which factors may yield successful human-robot interactions, many of these findings have been inconclusive or contradict one another. For example, some studies argue that a robot's gender impacts interaction success, whereas other studies state that a robot's facial expressions, and not its gender, impacts interaction success. Furthermore, few studies have assessed at the combined effect of multiple factors within HRI. Instead, previous research has analyzed the isolated effects of a robot's gender, or a robot's personality, on HRI success. The purpose of this study is to build off of prior work by analyzing the simultaneously effects of a robot's gender and personality on human-robot interaction.

In general, this study assesses how a robot's gender (male vs. female) and a robot's personality (introverted vs. extroverted) impact the success of a given human-robot interaction. The interaction success is measured on three dimensions: task duration, Robot Reaction Scale scores, and Robot Comfort scale scores. Based off of isolated findings in robot gender and personality, I hypothesize that an extroverted female robot will produce the most successful human-robot interactions.

# 2 Background and Related Work

## 2.1 HRI from a Psychological Perspective

Previous research has shown that Human Robot Interaction (HRI) differs from Human-Computer Interaction (HCI) mainly because HRI involves a more personable and emotional interaction between the human and the technological agent. To be more specific, Forlizzi and DiSalvo [1] found that humans tend to automatically associate robots with living creatures, and will interact with robots as such. Furthermore, people tend to develop strong affective and emotional attachments to robots. However, this is not the case with other technological agents, such as computers or tablets. Additionally, studies show that negative attitudes and emotions towards robots directly influence a person's behavior in a human-robot interaction. More specifically, Nomura et al. [9] determined that there are certain psychological factors which contribute to poor human-robot interaction. For example, a person who displays social anxiety, technophobia, or communication apprehension will likely experience more discomfort and anxiety when interacting with a robotic agent, and will behave in a more reserved manner. Due to these psychological factors and their impact on HRI, this study incorporated a baseline Negative Attitudes Towards Robots scale [9]. This scale measured the negative attitudes and emotions a person may have towards robotic agents, and individuals completed it prior to interacting with the robot.

## 2.2 Conducting an Analysis of HRI

Human-Robot Interaction can be evaluated over three main dimensions: visceral factors of interaction, social mechanics, and social structures. Visceral factors refer to a person's biological and instinctual response when interacting with a robot (i.e. a person's first impression). A robot's size, shape, speed, and patterns of movement can affect visceral factors. Social mechanics refer to higher-level communication techniques that occur during an interaction (i.e. gestures, facial expressions, tone of voice, etc.). By altering the higher-level communication techniques implemented within a robotic agent, the perceived disposition and personality of the robot is affected. Social structures refer to the setting the interaction takes place in (i.e. the cultural environment), and how this setting may influence the interaction. This category also refers to the impact a robot may have in a given setting (i.e. the emotional impact of a robot's presence on humans over time). These dimensions were developed by Young et al. [14]. For the purpose of the current study, HRI quality will be analyzed over the second previously listed dimension: social mechanics. More specifically, higher-level communication techniques of facial expressions and voice pitch were used to establish the robot's personality and gender in this study.

## 2.3 Task-Driven HRI

Studies have also demonstrated that HRI improves if a robot's appearance, behavior, and social cues match its task/purpose. Goetz et al. [3] found that people preferred friendly robots for highly sociable tasks. Additionally, people tended to comply more with a robot whose demeanor matched the seriousness of a task. Further task-related HRI studies have analyzed how to generate a shared mental model between a collaborator and a robot during an interaction. More specifically, Tabrez and Hayes [13] explored enabling a system to detect disparity between a robot and the human collaborator, finding the source of the disagreement, and ensuring that the robot provides human-interpretative feedback to the user. Results showed that participants found the robot to be more helpful/useful when it provided an explanation for why a failure/discrepancy may occur. Additionally, when the robot gave justifications for its actions, it led to a more positive user experience in which the participant viewed the robot as more intelligent. Conversely, when the robot did not provide detailed feedback in regards to discrepancies, the participants did not trust the robot and were more skeptical of its behavior. Although robot justification was not necessary for the current study, findings from these task-driven HRI studies still relate to this study's experiment. After interacting with the robot, the participants completed a Robot Reaction scale. This scale contained items that measured the participants perception of the robot's capabilities (i.e. if they thought the robot would be a good college campus tour guide). Since tour-guiding is a highly sociable task, and prior work demonstrates that friendly-coded robots are preferred for highly sociable tasks, it is likely that participants who interacted with the extroverted robot will perceive the robot to be highly capable for this task.

## 2.4 Gender and HRI

For the purposes of this study, analyzing previous research in gender and Human Robot Interaction is essential. The majority of research that involves the manipulation of a robot's gender is conducting within the area of persuasive robotics. This area of social robotics refers to analyzing the characteristics of a robot that may impact its influence on the human decision-making process. Siegel et al. [12] conducted an investigation of persuasive robotics and gender, in which they discovered that men were more influenced by female robots than male robots, whereas women had little preference for a robot's gender (the robot's gender did not affect its influential capabilities). Additionally, the authors found that participants tended to rate robots of the opposite sex as more credible, trustworthy, and engaging; this effect was the strongest between male subjects and female robots. Interestingly though, other studies showed opposite effects. For example, Ghazali et al. [2] found that although participants experienced higher psychological reactance when interacting with a robot of the opposite gender, the gender of a robot did not affect the participants' level of trust. Instead, these authors established that a robot's perceived level of trust is highly dependent on its facial expressions and not its gender. These contradicting findings indicate that additional research in HRI needs to be conducted in order to verify how a robot's gender impacts how its perceived by humans. The current study further explores how a robot's facial expressions and gender impact HRI success.

Other studies in HRI have analyzed how the gender of a participant may predict their perception of a robot. Schermerhorn et al. [11] analyzed participant gender in robot interactions via measures of social facilitation. Social facilitation is a phenomenon in which people show increased levels of effort and performance when in the presence of others, compared to being alone. In this case, social facilitation was analyzed within the presence of a robotic agent. These researches found than men tend to perceive robots as more human-like and show higher evidence of social facilitation during an interaction, whereas women tend to perceive robots as more machine-like and show lower levels of social facilitation during an interaction. Although the concept of participant gender in HRI is important when conducting a study, this measurement was excluded from this current study due to its small sample size.

### 2.5 Personality and HRI

Similar to gender and HRI, this study also builds off of previous research in robot personality and HRI. Ensuring that a robotic machine contains a measurable personality proves to be a difficult task. Therefore, several studies utilize a robot's facial expressions as personality indicators. Ghazali et al. [2] found that robots with upturned eyebrows and lips evoked more trust within an interaction compared to robots that displayed eyebrows pointing down and lips curled downwards at the edges. However, additional research in robot personality and HRI exists beyond facial expression display. For example, Lee et al. [5] conducted a study in which they tested degrees of extroversion and introversion within both the robot and the participants. Results showed that the participants could accurately recognize a robot's personality based on its verbal and nonverbal behaviors within their implementation. In addition, Lee et al. [5] found that successful interactions occurred when participants interacted with a robot personality that was complementary to their own personalities, more so than interacting with robot personalities that were similar to their own personalities. Building off of this, Robert [10] showed that extroversion plays a key role in understanding HRI. Extroverted participants responded more positively to robot interaction. In general, humans responded more positively to robots with extroverted personality characteristics. Similarly, Mou et al. [8] found that extroverted robot personalities produced desirable social outcomes in HRI. However, Robert [10] also noted that positive findings with extroverted robot personalities may be due to the fact that extroversion is an easier trait to display in robot personalities compared to other traits, especially in brief interactions. This study builds off of prior work as it incorporates extroverted and introverted robot personalities via displayed facial expressions.

### 2.6 Additional Contributing Factors in HRI

Studies have shown that there are additional factors that may cause HRI to go poorly. For example, Lee et al. [6] found that people are reluctant to interact with a social robot if the robot is taller than them. Moreover, Ho et al. [4] illustrated that a person's discomfort may increase if a robot's life-likeness appearance exceeds a certain threshold, but it does not display realistic human-like behavior (The Uncanny Valley Theory). The current study accounted for these factors in its experimental design; the robot was not exceedingly tall, and it did not contain hyper-realistic facial expressions.

# 3 Methods

## 3.1 General Overview

For this experiment, participants were first asked to complete a Negative Attitudes Towards Robots Scale (NARS) [9]. After they completed this scale, participants interacted with the robot. This interaction included a dialogue section (similar to an interview) and a task section. Once the interaction was complete, the participants were asked to fill out a Robot Comfort Scale and a Robot Reaction Scale.

## 3.2 Participants

The participants were 29 Union College students (twelve men, sixteen women, one nonbinary person) of ages 18 to 22 (M= 20.62, SD= 1.18). About half of the participants were White/European (51.72%), 23.79% were Asian, 10.34% were Black/African American, 17.24% were multiracial, and 6.90% identified as some other race. This experiment was conducted on campus at Union College, in the Collaborative Robotics and Computer Human Empirical Testing Laboratory (CRoCHET Lab). Participants for this study were gathered via demonstrated interest through the psychology department's online recruitment system and well as campus announcements. Incentive for participation was offered as $16.00 USD or as extra credit for select psychology courses. This study was ran consecutively with another HRI study that analyzed the effects of robot eye gaze on task performance. Participants completed the current study either before or after the eye-gaze experiment; the order for which the studies were administer was alternated for each trial. Participants were given a five minute break in between the two experiments.

## 3.3 Measures

Three scales were used during this study. Prior to interacting with the robot, the participants were asked to complete the Negative Attitudes towards Robots Scale (NARS) [9]. Good initial Reliability of the NARS scale was demonstrated by Kaplan et al. using Cronbach's Alpha ($\alpha$ =.880). This scale was used to quantify the participants' baseline comfort level towards robots in general. Sample items from this scale included: "I would feel uneasy if robots really had emotions", "I feel that in the future society will be dominated by robots", and "the word "robot" means nothing to me". Participants rated each of these items on a Likert scale that measured how much they agreed with each statement, from "strongly disagree" to "strongly agree".

After interacting with the robot , the participants completed a Robot Comfort Scale (RCS) and a Robot Reaction Scale (RRS). These scales showed decent initial reliability using Cronbach's Alpha ($\alpha$ =.785) and ($\alpha$ =.670) respectively. The RCS was used to quantify the participants' comfort levels during their interaction with the robot. This scale contained modified items that were originally developed by (CITE). Sample items from this scale included: "I felt comfortable interacting with the robot" and "I felt comfortable being in the same room as the robot". The RRS scale was used to quantify the participants' general reaction to interacting with the robot, as well as their perception of the robot's overall functionality. This scale contained items that were generated specially for purposes of the current study. Sample items from this scale included: "I felt like I had a productive and engaging conversation with the robot" and "I think the robot would be a good tutor and/or study companion". Participants rated the items on both scales on a Likert dimension that measured how much they agreed with each statement, from "strongly disagree" to "strongly agree".

## 3.4 Procedure

The interaction between the robot and the participant consisted of the robot asking the participant a variety of questions in an interview-like manner. Half of these questions were icebreaker questions, and the other half were Union-specific questions to target the participant's opinion as a student. Some of the icebreaker questions included: "how has your day been so far?" and "are you a morning person or a night owl?". Some of the Union-specific questions included: "which of the following places is your favorite place to study on campus: "Shaffer Library, you bedroom, or ISEC?" and "as an undergraduate student, which you do you prefer: semester or trimesters?". The robot responded to the participant's choice in between questions in order to simulate conversational flow.

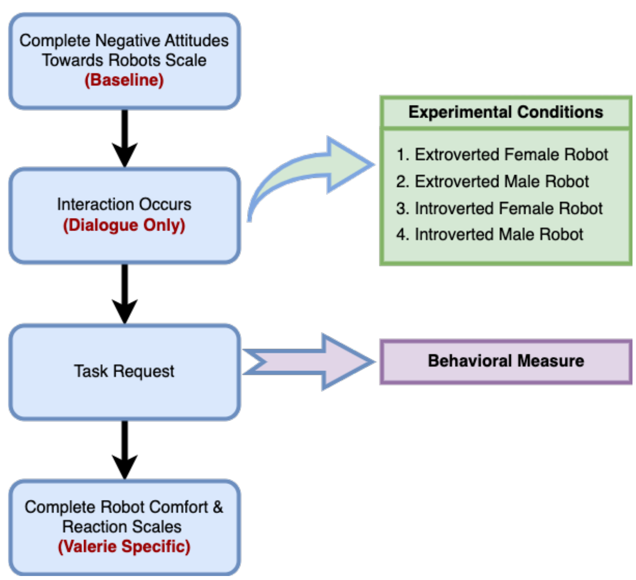


Figure 1: Methodology Flowchart

During the interaction, the participants were randomly assigned to interact with either a male or female robot. The robot's gender was operationalized via its voice. More specifically, a higher-pitched

**Question**: "If you had the funds to upgrade one of the following building on campus which would it be: Reamer, Schaffer Library, or the Nott?"

**Extroverted** Response: "Reamer is an important building on campus!"

**Introverted** Response: "Oh... Reamer, that's an interesting choice."

Figure 2: Speech Response Content Example

voice signified a female robot, whereas a lower-pitched voice is signified a male robot. In an orthogonal manipulation, the robot either manifested an introverted or extroverted personality. More specifically, the interview questions that the robot asked the participant did not vary between the experimental condition groups. However the robot's response content varied between the extroverted and introverted conditions. More specifically, the robot was coded to respond in a more serious manner in the introverted condition compared to the extroverted condition. These responses were hard coded according to the participant's reply. Furthermore, the robot's facial expressions also varied between extroverted and introverted conditions. All of the robot's responses were predetermined prior to the start of the experiment. Additionally, the participants were not made aware of their assigned robot-interaction condition until after the experiment concluded.

After the dialogue portion of the interaction had finished, the robot asked the participant to complete a task. This task required the participant to solve a worksheet of unscrambling twenty words (anagrams). The participants were informed that they were allowed to stop completing the task whenever they liked, although a fifteen minute limit was also implemented. This limit was implemented because ten of the twenty anagrams were unsolvable (the participants were not made aware of this fact until the experiment concluded). The purpose of this task is to provide another measure for determining the success of the interaction; task duration was used as a behavioral measure.

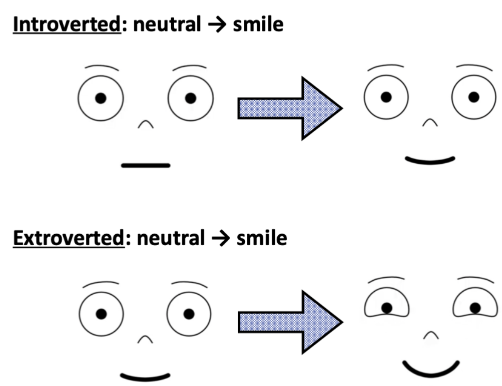


Figure 3: Personality-Based Facial Expressions

## 3.5 Tools and Technology

The social robot that was used in this experiment is a PeopleBot named VALERIE. VALERIE's named was altered depending on its gender condition: Stephan for male, Stephanie for female. The robot has the ability to move, speak, and display a variety of facial expressions. the robot's speech was developed using Amazon Polly, and its facial expressions were rendered in a browsing window, using existing Javascript libraries for 2D graphics and animation. The primary software used with VALERIE is The Robotic Operating System (ROS), which allows for message passing of speech, movement, and facial expression display commands.

These commands were sent via a Graphical User Interface (GUI) developed by the experimenter. The experiment was conducted within a Wizard of Oz method, in which the participant was observed via a two way mirror.

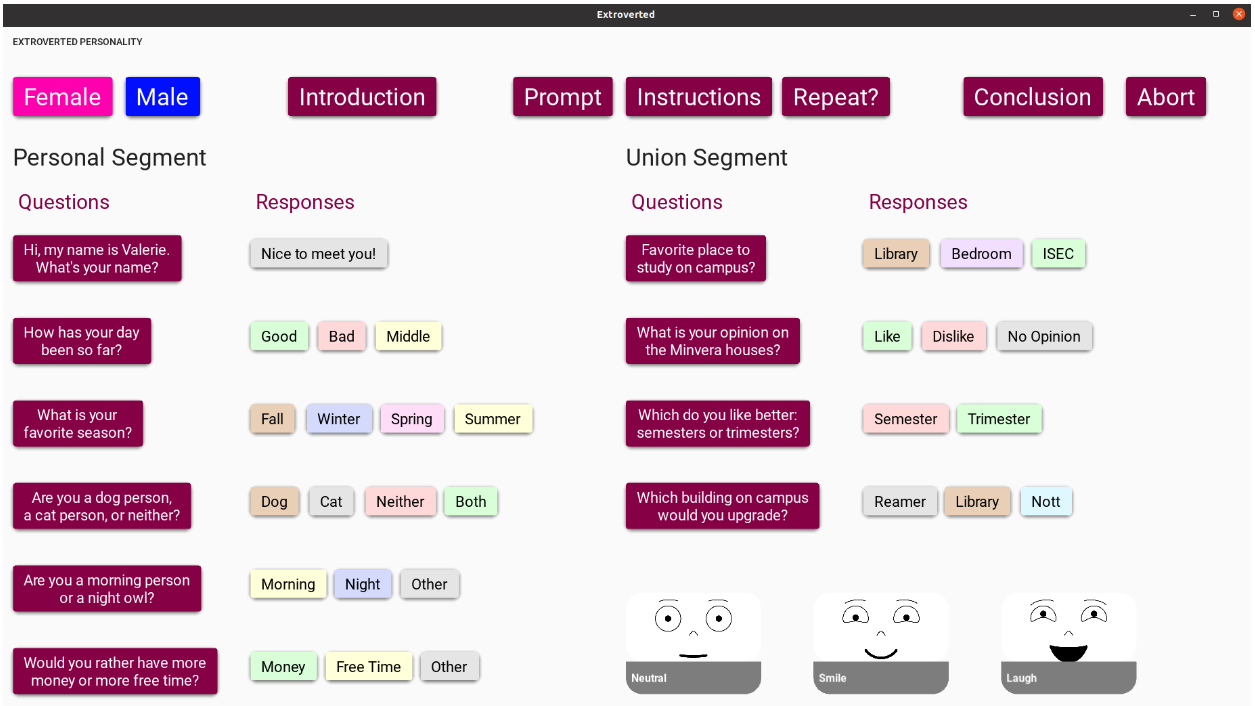


Figure 4: The Grpahical User Interface

# 4 Results

Analyses of variance (ANOVA) were performed on three dependent variables: (1) task duration, (2) Robot Reaction Scale scores, and (3) Robot Comfort Scale scores.

In regards to task duration (which was measured in seconds), there was no main effect of robot gender F(1,25) = .821, p = .373. In other words, not accounting for the effects of robot personality, there was no isolated significant effect of robot gender on the amount of time the participants took to complete the task. However, participants who interacted with the male robot (M = 664.73, SD = 264.65) took longer to complete the task than participants who interacted with the female robot (M = 572.57, SD = 293.83). Additionally, there was no main effect of robot personality F(1,25) = .697, p = .412. In other words, not accounting for the effects of robot gender, there was no isolated significant effect of robot personality on the amount of time the participants took to complete the task. However, participants who were interacted with the introverted robot (M = 665.00, SD = 302.432) took longer to complete the task than participants who interacted with the extroverted robot (M = 578.47, SD = 256.51). Finally, in regards to task duration, the was no interaction of robot gender and robot personality $F(1,25) = .099$, $p = .755$. In other words, there was no combined effect of robot gender and robot personality on how long the participants took to complete the task.

In regards to Robot Reaction Scale scores, there was no main effect of robot gender $F(1,25) = .114$, $p = .738$. In other words, not accounting for the effects of robot personality, there was no isolated significant effect of robot gender on how the participants' general reaction to interacting with the robot. Participants who interacted with the female robot (M = 13.73, SD = 4.27) rated their general reaction similarly to participants who interacted with the male robot (M = 3.92, SD = 2.00). Additionally, there was no main effect of robot personality $F(1,25) = 1.132$, $p = .298$. In other words, not accounting for the effects of robot gender, there was no isolated significant effect of robot personality on the participants' general reaction to interacting with the robot. That being said, participants who interacted with the extroverted robot (M =14.33, SD = 3.56) rated their general reaction marginally higher than individuals who interacted with the introverted robot (M = 13.29, SD = 3.56108). Finally, in regards to Robot Reaction Scale scores, the was no interaction of robot gender and robot personality $F(1,25) = 1.861$, $p = .185$. In other words there was no combined effect of robot gender and robot personality on the participants' general reaction to interacting with the robot.

In regards to Robot Comfort Scale scores, results showed that there was no main effect of robot gender $F(1,25) = .070$, $p = .793$ and no main effect of robot personality $F(1,25) = .682$, $p = .417$. In other words, there were no isolated effects of the robot's gender or the robot's personality on how comfortable participants felt during the interaction. However, there was an interaction between robot gender and robot personality $F(1,25) = 4.660$ , $p = .041$. Among participants who interacted with the male robot, participants felt marginally more comfortable with an extroverted robot (M = 13.14, SD = 2.12) than with an introverted robot (M = 14.71, SD = 1.60; $t(13) = 1.70$, $p = .25$). Conversely, among people who interacted with a female robot, participants felt marginally less comfortable with an extraverted robot (M = 15.38, SD = 3.54) than with an introverted robot (M = 11.86, SD = 4.49; $t(12) = -1.566$, $p = .50$).

# 5 Discussion

## 5.1 Analaysis of Data

The results from this study somewhat support the original hypothesis. I hypothesized that the extroverted female robot will produce the most successful human-robot interactions. The current findings indicate that participants felt slightly more comfortable interacting with the female extroverted robot compared to the female introverted robot. However, my hypothesis did not account for the converse effects found within the male robot condition. More specifically, I had not anticipated that participants would feel slightly more conformable interacting with the introverted male robot compared to an extroverted male robot. These findings illustrate how imperative it is to perform multidimensional analyses within studies of HRI. Previous work in this field typically focuses on isolated factors in regards to interaction success (i.e. robot gender or robot personality). However, by analyzing these facts concurrently, I was able to demonstrate that robot gender and robot personality concretely interact with and influence one another. In other words, there is a combined effect of robot gender and robot personality on individuals' comfort during human-robot interaction. This study showed that the notion of extroverted robots yielding desirable social outcomes is not generalizable on dimensions of robot gender. In fact, the interaction between dimensions of robot gender and robot personality can lead to unexpected results.

## 5.2 Strengths and Limitation

The primary limitation of this study was that there existed technical difficulties within the robot setup. More specifically, the speech software used in this experiment was not compatible with the PeopleBot's current version. In order to remedy this, the robot's face was displayed on a CPU desktop screen monitor. This monitor was raised to a similar height as the original robot, and the keyboard and mouse were removed from the setup. Nevertheless, the setup still had some missing hardware compared to the original robot (i.e. base and wheels). Therefore, the participants may have perceived the monitor to be less robot-like compared to the original PeopleBot, which could have limited the interaction success.

Another limitation of this study was that it contained a small sample size of a specific population (college students) and demographic background. This limitation significantly hinders the study's internal and external validity. In regards to interval validity, having a specific population may have introduced certain biases within the experiment. For example, many young adults are familiar with technological agents compared to other age demographics. Therefore, if this study was conducted with a larger age range, the results may have differed. More specifically, there may have been fewer findings of interaction success and lower comfort ratings overall. In regards to external validity, having a small sample size significantly impairs the ability to generalized this study's findings to other contexts. In other words, this study only demonstrates the current findings specific to the population that was involved. Additionally, studies with small sample sizes tend to have low statistical power, as well as inflated false discovery rates. If this study was replicated with a larger sample size it is likely that statistical power would increase, and new findings may emerge (given that only one of the three depended variables yielded statistical significance). Overall, in order to improve the internal and external validity of this study, replication should occur with a larger and more diverse sample size.

## 6 Conclusion

This study analyzed how a robot's gender (male vs. female) and a robot's personality (extroverted vs. introverted) impacts the success of human-robot interaction. The success of the interactions were measured on three dimensions: task duration, participants' comfort scores, and participants' reaction scores. Findings show that participants' comfort scores were significantly impacted by the robot's gender and personality. Specifically, participants felt slightly more comfortable interacting with the female extroverted robot compared to the female introverted robot, and participants felt slightly more conformable interacting with the introverted male robot compared to an extroverted male robot.

Future research can build upon these findings in several ways. Mainly, it would be important to replicate this study such that it takes into account the gender and the personality of the participants. Prior research has demonstrated that humans tend to prefer interacting with a robot whose gender is opposite to their own, as well as a personality which is complementary, instead of similar to, their own. Incorporating these predicting factors is necessary in order to generate additional conclusions. For example, introverted participants may feel more comfortable interacting with the extroverted robot, and extroverted participants may feel more comfortable interacting with an introverted robot. Additionally, female participants may feel more comfortable interacting with a male robot, and vice versa. That being said, there are many areas that are still left unaccounted for within these hypotheses (i.e. individuals who consider themselves to be ambiverts, or individuals who identify as nonbinary). Also, adding in these factors may produce unanticipated results due to interactions between variables, similar to how robot extroversion only produced HRI success for female-coded robots (and not male-coded robots) in the current study. In general, although this study produced concrete findings for how a robot's gender and a robot's personality impact HRI, there are many areas in which additional analyses can be performed.

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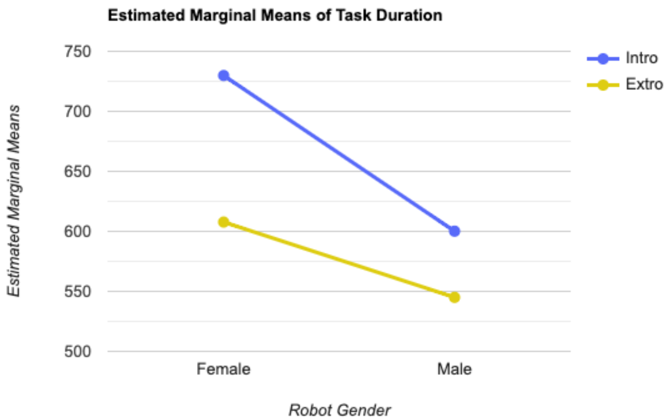


Figure 5: Task Duration Data Visualization

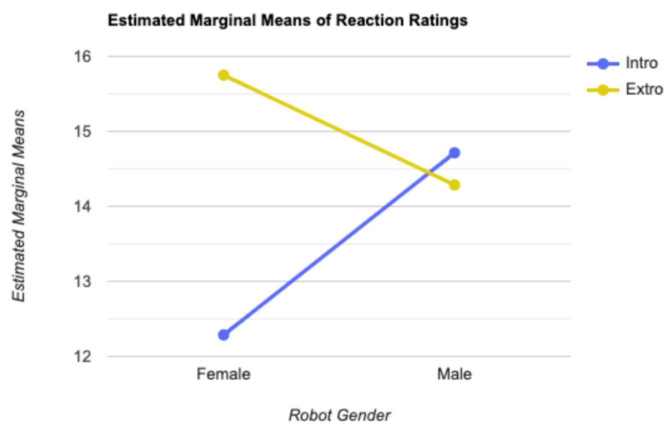


Figure 6: Robot Reaction Scale Scores Data Visualization

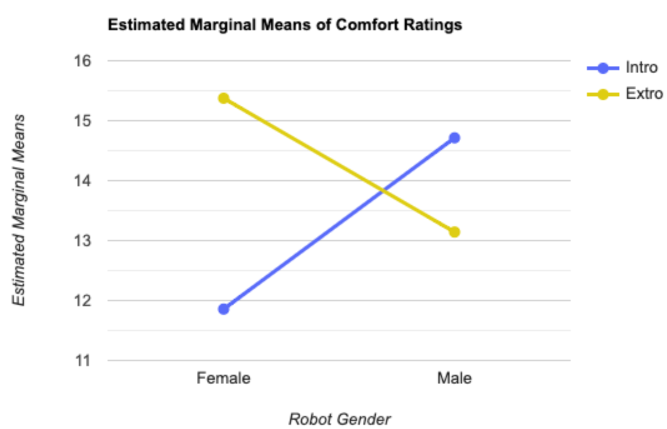


Figure 7: Robot Comfort Scale Scores Data Visualization

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