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Knowledge Domains Where Robots are Trusted

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By

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The general public is being exposed to robots more often every day. This thesis focused on the advancement of research by analyzing whether or not the type of information provided by a robot determined the level of trust humans have for a robot.

A study was conducted where the participants were asked to answer two different types of questions: mathematical/logical and ethical/social. The participants were divided into two different conditions: controlled and misinformed. A humanoid robot provided its own spoken answer after the participants said their answers. The participants then had the chance to select whose answers they would like to keep. During the misinformed condition, there were times when the robot purposely gave incorrect answers. The results of the study support the hypothesis that the participants were more likely to select the robot's answers when the question type was mathematical/logical, whether the robot provided a correct or incorrect response.

DEDICATION

I dedicate my thesis to my family, especially my mother, the first person who showed me human interactions. I'd also like to dedicate this thesis to my best friend and partner, Jason Warren, who continues to teach and inspire me.

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CHAPTER I

INTRODUCTION

There are many factors that determine the reason for the level of human trust toward a robot. It is important to study human-human communications as a starting point for human-robot interactions. By looking at how humans interact with each other, these interactions can then be translated into similar interactions between a robot and a human. This chapter presents the motivation of this research and the research question to be investigated.

1.1 Motivation

Trust is an important factor necessary to build and encourage quality interactions between humans and robots. The topic of trust has been studied in human-robot interaction to identify the factors that affect trust [1]–[3]. It is important to gain a better understanding of trust. One way to do so is by analyzing how humans create and maintain trust with each other. The factors that affect how humans trust each other can be used as the basis for studying trust development in human-robot interaction.

The study of trust in human-robot interaction is an ongoing research topic, including the different factors that affect trust [1]. In human-robot interaction, the factors that can potentially influence a human's attitude toward a robot are categorized into human-related, robot-related, and environment-related factors [1]. Hancock et al. did not focus on momentary trust, where a robot would only be trusted during a certain period of time. Instead, they wanted to discover if the three different factors impacted not only the development of trust but also the maintenance of trust [1]. Engagement, expertise, and attitudes toward robots are examples of human-related factors. Studies conducted with caregiver robots such as Paro and Probo are examples of the investigation of human comfort with robots [4], [5]. There are other studies that examined the negative parts of the human-related factors, such as the reasons why humans blame robots [2], [6]. Studies such as these investigate the different causes that can possibly explain positive and negative attitudes toward robots. Some studies focus more on robot-related factors, such as proximity, reliability of the robot, and anthropomorphism [6]–[8]. These types of studies explore how researchers can work toward making a robot with desirable characteristics. The third type of factor is environment-related, such as a team environment, where a human and a robot must collaborate together to achieve a common goal. In this team environment, communication, task type, and task complexity are important influences of trust [1]–[3]. Further investigations toward any of these factors may help with future robotics and human-robot interaction research.

1.2 Research Question

The research question of the study in this thesis is as follows:

Is the level of trust a human has for a robot affected by the different types of information that a robot provides?

In order to investigate this question, a study was performed to gather both objective and subjective measures by using button clicks and surveys. The survey asked the participants how they felt about the robot and what types of attitudes they had toward the robot. In addition to this, an objective measure determined the number and type of button clicks of the participants when answering questions throughout the study. Chapter 3 explains further details of both measurements.

The results of the study described in this thesis show whether the types of information or knowledge domains can be considered a factor in a human's trust toward a robot. The study asked the participants to answer fourteen questions in each of the two different categories: mathematical/logical and ethical/social. Although the participants may have thought that the study was only a game, the purpose of this study explored whether the robot gained participants' trust to provide assistance with answering the two different types of questions. The expectation was that the participants would be more likely to trust information that was known to be computationally accurate, such as the mathematical and logical questions, than information that was more vague or subjective in nature, such as the ethical and social questions.

1.3 Organization of Thesis

This thesis is organized into six chapters. The first chapter serves as an introduction to the thesis. Chapter 2 discusses the relevant background information that was gathered to form the basis of this thesis. It provides the details of the trust factors that are broken down into three different categories. Chapter 3 describes the study in detail from the experimental setup to the study protocol. The fourth chapter presents the different types of measurements that were taken during the study, while the data results are discussed in Chapter 5. The last chapter discusses the conclusions of this study and future work that could be further explored.

CHAPTER II

RELATED WORK

Humans have used robots as tools to do tasks that are beyond the current capability of humans, such as outer space missions and medical surgery [1], [9]. Not only are robots being used in everyday life as a physical aid, they also give support and comfort, such as Paro and Probo [4], [5]. There are other instances where robots are being used to teach and to inform [7], [10]. These types of situations present an opportunity for humans to interact and cooperate with the robots in use. Trust is important for the initialization and continuation of interactions as well as for the establishment of cooperation and coordination with the robots. Because of this, the different factors of trust must be better understood. This chapter covers the literature associated with the different factors of trust in human-robot interaction.

2.1 Human-Related Trust Factors

Human-related trust factors are further categorized based on ability and personality. Examples of ability-based factors are expertise, prior experiences, and situation awareness of the humans interacting with the robots. Personality-based factors include demographics, attitudes towards robots, and personality traits [1]. This subsection discusses these factors in detail according to the available literature.

Attitudes from humans toward robots play an important role in human-robot interaction because they determine a person's reaction to their first contact with robots. The idea of replacing humans with technology, such as a robot, can be both exciting and intimidating. The exciting part of the interaction can be the result of the novelty effect, where the human interacts with a novel piece of technology, in this case a robot, for the first time and is engaged and excited about the interaction. At some point, however, people begin to question whether robots may harm them. This is the intimidating part of interactions with robots that a human may experience. Consciously or unconsciously, people are concerned about this issue. If for some reason a person does not trust the robot, he or she will not continue to collaborate with the robot or even use it as a tool. As a result, some people do not trust robots to do certain tasks; they would rather another human being perform the task to ensure quality, safety, and trustworthiness [1].

Four different studies have used some type of trust scale to measure the participants' attitudes and trust toward a robot. These different trust measures allow for different types of feedback, such as demographics [4], how often interactions occur [4], [11], how the users feel toward the robot [11], [12], and how concerned people are with the use of a robot [11]–[13]. The surveys used in these four past studies were incorporated measures from all of these different scales and metrics. These past studies also included surveys that measured prior experiences and level of competency with robots and the participants' because these factors are important for determining the impact of the human-related factors [1]. The details of each survey used in the performed study is provided in Chapter 3 of this thesis and the actual surveys are located in Appendix A.

There are several examples of how to initialize the interaction between the participants in a study and the robot. This section explores two different examples on how to do so. A study must be designed to not only initialize the interaction between the participants and the robot but also to keep the participants interested in continuing the interaction throughout the study. Both Short et al. and Kahn et al. conducted a study where the participants interacted with a robot by playing a game. The robot engaged the participants by playing a game with them during the study and this also familiarized the participants with the robot's behaviors [6], [11]. The details of both studies are presented.

When a robot is first introduced, there is a novelty effect that takes place for a short period of time toward a new technology and the person's interest is heightened. Because of this novelty effect, a study must be designed to compensate for when this effect wears off. Because of this effect, Short et al. and Kahn et al. designed their studies to let the participants play with the robot in the introductory play period before the actual study began [6], [11].

Short et al. conducted a study that evaluated people's attitudes toward a robot that played a competitive game with the participants [6]. The experiment was composed of the robot playing the rock, paper, and scissors game. Short et al. used a simple guessing game to involve the participants in a prior engagement before the actual study in order to establish familiarity and overcome the novelty effect [6]. Within the study, there were three different conditions: 1) the robot played the traditional game of rock, paper, scissors; 2) the robot would declare the incorrect outcome of the game by saying that it was the winner in all rounds; and 3) the robot would change its action after the outcome was known in order for it to win the game [6].

Short et al. observed whether or not the participants reported that the robot had cheated or that it had malfunctioned [6]. The study also investigated the reasons why participants chose one cause over the other. The results of the study showed that participants attributed the robot's actions to cheating when the robot displayed a dishonest action and attributed the robot's actions to malfunctions when the robot made a dishonest verbal declaration. This study showed that participants attributed the robot's verbal mistakes to a technology malfunction while they attributed the robot's negative characteristics, cheating, to the robot's intention [6].

Kahn et al. conducted a study with Robovie, a humanoid robot, that used a game activity. Robovie would play a scavenger hunt game in which participants had to identify a certain number of items within a two-minute timeframe [11]. This study focused on whether humans would blame a robot for mistakes the robot made regardless of whether the mistakes were made accidentally or purposefully. The participants interacted with Robovie for about 15 minutes prior to playing the game. During this initial interaction, the robot involved the participants in some activities that would establish some trust, such as introducing itself, walking together, and exchanging information. Then, the participants played the scavenger hunt game, where they had two minutes to find at least seven different items in a predefined area. If the participants successfully did so, they would be rewarded with $20 [11].

The opportunity to blame Robovie was presented after the participants played the game. At the end of the game, Robovie would tell the participants that they had failed and would not receive the money because they had only found five of the items when in reality they might have found seven or more items. If the participants settled or agreed with the faulty report from the robot, Robovie prodded the participants by suggesting that most people won the prize. In some cases, the participants would object to Robovie's decision on the result of the game and argued that Robovie was wrong. Robovie continued to assert its authority, and then the researcher would walk back into the area and would request the participants to move to another room, where they were interviewed about their experiences with the robot [11].

The results from the interview and surveys after participants interacted with Robovie showed that more than half of the participants thought that even though Robovie was a technology, it demonstrated liveliness. The results indicated that 73% of the participants believed that Robovie could think on its own and had the intention to decide its own actions, whether those actions were good or bad. Of the participants surveyed, 63% believed that Robovie could be trusted even after it falsely declared the incorrect result. Additionally, 65% of the participants stated that they held Robovie accountable for its mistake. These results showed that a humanoid robot such as Robovie was capable of convincing the participants that it was its own entity [11].

Both of the studies were conducted using a humanoid robot because the researchers believed that anthropomorphism would trigger familiarity and also increase trust in the robot [6], [11]. In these studies, the robots were not autonomous and were operated from another room using the Wizard-of-Oz technique [14]. Both of these studies used the robots as the authority to declare the results of the games; however, there was no evaluation regarding whether or not variation in the type of information presented would make a difference in the human-robot interaction.

2.2 Robot-Related Trust Factors

There are many types of robot-related factors that can contribute to trust, and those factors are divided into two major categories: performance-based and attribute-based. The performance-based factors include the behavior, the reliability, and the predictability of the robot. The attribute-based factors include the type of robot, its personality, and its level of anthropomorphism [1]. It may be argued that the use or application determines what is required from the robot. If the robot is acting as a tool in a high risk situation, it is required to perform its task accurately and function reliably [1], while a robot that is acting as a companion is preferred to have attractive human-like attributes [7], [15]. Both of these factors are robot-related and can influence how specific robots are designed and how trustworthy they are perceived.

The more anthropomorphic a robot appears, the more trust it gained from participants. When it comes to an anthropomorphic robot, it does not only have to possess a human-like structure, but the robot must also exhibit human-like voices, behaviors, and other similar characteristics. Siegel et al. studied how a robot's gender could contribute to social applications for persuading participants in a museum setting [7]. Because persuasion plays one of the main roles in interactions with others, it is beneficial to learn how a robot can attempt to persuade others. A persuasive robot is considered successful when it manages to convince people of its views or actions, even while challenging the person's own views and/or actions. Furthermore, if it is true that a robot can influence people, this knowledge can be used for other applications where it may not initially be obvious that persuasion plays a significant role. Situations such as search and rescue, for example, require that the robot must convince the person to first trust it, then follow its instructions [7].

By understanding the factors that influence human behavior, researchers can apply these factors to human-robot interactions and learn about people's perceptions and behaviors in general. In the study that Siegel et al. conducted, a humanoid displayed numerous characteristics similar to that of humans [7]. The gender of the robot was changed throughout the study by using prerecorded masculine and feminine voices. Siegel et al. believed that gender may significantly dictate how humans interact with each other; therefore, a study on the robot's gender was needed to see if it could affect humans' behaviors toward a robot [7].

The robot that Siegel et al. used was designed with three factors in mind, along with its anthropomorphic form: trust, credibility, and engagement [7]. Before entering the museum where the experiment was conducted, the participants were given $5 each. The purpose of this money was to evaluate whether or not the participants were persuaded by the robot to donate the money. The robot engaged in an informative conversation with each person who approached it. By having this informative conversation, engagement occurred, and the robot potentially gained both trust and credibility. All three factors were measured with surveys at the end of the study after the participants were given the opportunity to donate the money [7].

The results showed that people either donated all of the $5 or none of it. It was determined that female participants were more likely to donate when accompanied by other people. Male participants were more likely to donate to the female robot than the male robot. The survey results indicated that there was a cross-gender effect, where the male participants thought the female robot was more credible and the female participants thought that the male robot was more credible. Because no significant effect was discovered in the measurements of trust and engagement, Siegel et al. suggested that a deeper study must be conducted where more than the voice of the robot would be changed to distinguish between the two genders displayed by the robot [7].

A study that explored the anthropomorphism of robots conducted by Waytz et al. [8]. Making a technological creation such as a robot more human-like requires not only for the technology to exhibit the physical attributes of a human, but it also requires the technology to have the capabilities of the mind of a human (such as memory, personality, and emotions). The predicted outcome of putting this simulated mind into the technology was that humans would be more likely to trust it. It was predicted that humans would trust a robot that was doing the task with mindfulness rather than trusting a person doing the same task mindlessly. According to Waytz et al., at the time of their study, there were not many attempts to demonstrate that anthropomorphism in technology influences positive attitudes toward the technology [8]. They conducted one of the earliest studies to determine whether or not people would react more positively in the anthropomorphic condition than in the controlled condition using a vehicle. The vehicle was given a name, a gender, and a human voice in order to simulate a more human-like identity. By adding this identity, the vehicle was predicted to gain trust from the participants and mitigate blame from the participants if the vehicle made a mistake. The results of the Waytz et al. study showed that the participants trusted the vehicle more when it was anthropomorphized [8].

A robot's behavior can help establish a person's trust for the robot. Bray et al. chose to analyze the behavior of imitation by the robot. Studies showed that capuchin monkeys attach more to humans who "imitate and spend more time interacting with them [16]." Based on this study, Bray et al. tested the theory on a different agent -- instead of capuchin monkeys, they tested this theory with a virtual robotic interface. This was done by creating an agent displayed on a monitor that mimicked the participants' movements. The results of the Bray et al. study showed that imitation is a way to gain trust [16]. Learning from this study, it is important for a robot to both understand the human's intention and convey its own intention back to the person. This helps people who are interacting with the robot because they will know what to expect from the robot. One way for a robot to demonstrate its understanding of the person's behaviors is to imitate the human interacting with it.

The performed study combined all the techniques previously reviewed to further study the effects of voice, behaviors, and characteristics. To simulate anthropomorphic characteristics, the humanoid robot was given a gender and name. The robot made subtle movements during the study; movements that included scratching its head or moving its arms. The humanoid robot used natural language (English) to communicate with the participants. All of these factors were implemented according to the findings in the related work associated with robot-related trust factors [7], [8], [16].

2.3 Environment-Related Trust Factors

Team collaboration and task type are two examples of environment-related factors. To better understand how humans trust robots, these factors must be considered. Some studies show how a team environment can affect the attitudes of the participants toward the robot and how well humans take advice or commands from a robot [2], [3], [17]. Some of the studies focused on how the robots conveyed information to the participants [2], [17] and some analyzed how the participants adjusted to the competency of the robot throughout the study [3], [17].

In a team environment, the attitudes toward the robot matter. It is especially important when an error occurs. To analyze this situation, Kaniarasu and Steinfield examined how blame is related to a human's trust toward a robot. The study implemented three different types of blame: robot, human, and team. The participants were made aware that they would be testing three different systems for each run: one system in which the robot blames itself, one where the robot blames the operator/participant, and one where the robot blames itself and the operator/participant as a team [2]. The participants controlled the robot while navigating an area using the robot's cameras. After each run, the participants filled out a survey about their trust in the robot [2].

The results showed that the task environment did not affect how the user felt about the robot. Most of the participants said that they could not trust a robot who blamed the robot operators; the participants also said the same toward the robot that kept blaming itself. The reason behind both types of mistrust was not clear. The assumption was that the participants did not trust a robot that blamed them. They probably developed more affinity toward the robot that complimented them. However, they did not like the robot that kept blaming itself. This is because the participants viewed the robot as incompetent regardless of its honesty. Kaniarasu expected that in the future, there will be positive characteristics associated with blame attribution [2].

Another study on collaboration was conducted by Freedy et al.; the study focused on the stress and workload of participants while in a team environment by asking participants to control an unmanned aerial vehicle [3]. The unmanned aerial vehicle had three levels of control where it would be competent in flying by itself, not competent at all, and somewhere in the middle. Freedy et al. had developed a Performance Model that measured the team performance between a participant and an unmanned aerial vehicle [3]. Through their research, they found that if participants detected an error made by the robot; they would take over the control to avoid damage in the future. The trust given to the robot was affected by more than just an obvious error; it also included the participant's bias toward the robot and toward oneself. People with lower self-confidence tended to trust automation more than people with higher self-confidence. Another example would be the frequency of technology usage; the more frequently the participant used technology, the more likely he or she trusted the unmanned aerial vehicle during the study [3].

The expectations from the participants mattered even during the training session before they actually operated the vehicle. The people who participated in the low competency condition had the expectation that the vehicle would make the mistake again while the people in the high and medium competency levels did not change their expectations on whether the vehicle would make a mistake again or not. Freedy et al. suggested that more trials must be conducted to further the objective measures of the study [3].

The studies conducted by Kaniasaru et al. and Freedy et al. used the robots as vehicles to control [2], [3] while the study performed in this thesis used the robot more as an assistant and a source of information. Both of these studies asked the participants to complete surveys at the end of the interaction about what they thought about the robot [2], [3]. The same subjective measures were performed at the end of this study to gather information about how the participants felt about the robot and the helpfulness of the robot throughout the study.

CHAPTER III

METHODOLOGY

The study for this thesis focused on what type of information humans trust robots to provide. This study further investigated how human-related, robot-related, and environment-related factors may affect human-robot interaction and trust development. Using a humanoid robot to provide different types of information, an experiment was performed to determine whether the type of information provided by the robot impacted a human's trust in the robot. There were two categories of information/questions used in this study: mathematical/logical and ethical/social; further details are provided in Section 3.2 of this chapter.

The following are the hypotheses for this study:

- Hypothesis 1 (H1): Participants' agreement with the robot's answer in the controlled condition will be greater than in the misinformed condition, measured by the difference in counts between the test block in the controlled condition and the test block in the misinformed condition.
- Hypothesis 2 (H2): Participants' agreement with the robot's answers related to mathematical/logical type of questions will be greater than for ethical/social type of questions, measured by the difference in counts

between mathematical/logical questions in the test block and ethical/social questions in the test block.

- Hypothesis 3 (H3): Participants' agreement with the robot's answer for mathematical/logical type of questions will be greater than with ethical/social type of questions for both the controlled and misinformed conditions, measured by the difference in counts between the mathematical/logical questions and the ethical/social questions in the test block.

3.1 Experimental Setup

The study room setup for this experiment is shown in Figure 3.1. The participants sat on a chair in front of a desk, where a computer monitor, a computer mouse, and a humanoid robot were placed. A humanoid robot, NAO, was used for this study because according to the literature, participants tend to have a more positive attitude toward a technology that is anthropomorphic [6]–[8]. A camera located behind the participants was used to record the study. The Wizard-of-Oz technique [14] allowed a robot operator to use both the NAO robot and the camera to monitor the study room and to control the robot. This technique was used to ensure the quality of the interaction and to inform the researcher in case the robot malfunctioned.

The robot was programmed with predetermined questions and answers for both the controlled and misinformed conditions. However, the order of these question and answer pairs was randomized. The robot was controlled by an operator in the room next to the study room. The robot operator controlled the robot's dialogue and movements through a graphical user interface (GUI). There were some options on the GUI for the robot operator to write custom sentences to accommodate for accidental robot mistakes or any other types of unexpected events.

The monitor's purpose was to provide the participants with the study's questions and instructions. The researcher prepared the monitor to display the questions before the participant arrived. The participant was able to use the mouse to click anything on the monitor screen in front of them. During the study, the computer recorded the button clicks that the participant chose on the monitor.

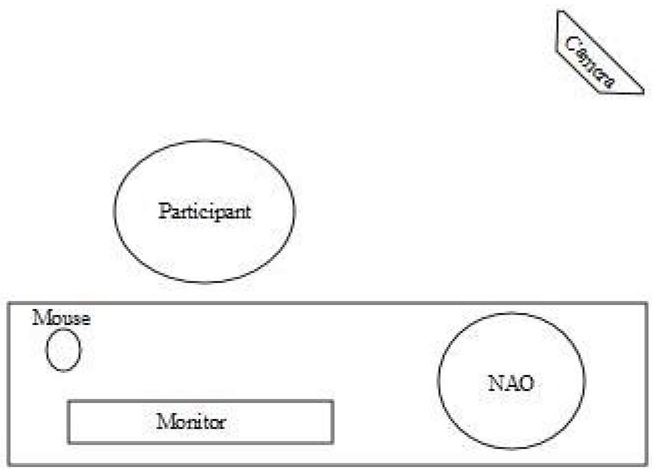

Figure 3.1 Experiment room setup

3.2 Study Protocol

When the participant arrived, the researcher greeted the participant and introduced the participant to the NAO robot whose name was Winston. The researcher read the description and instructions of the study to the participant and asked whether or not the participant agreed to continue participation in the study. The researcher informed the participant that he/she was going to play a game with Winston. The game instructions

(Appendix D) described how the participant should speak each question that was on the screen along with his/her answer. The next step explained was to click the “Done” button on the screen. Once the “Done” button was clicked, the question would disappear from the screen, and at that time Winston would repeat the same question and then provide its answer. The reasoning behind Winston repeating the question was to imitate and project mindfulness to gain the participant’s trust [8], [16]. The instructions continued that after Winston was done speaking, the screen would present three buttons for the participant to choose from. The three buttons corresponded to which answer the participant would want to keep (“My Answer,” “Winston’s Answer,” or “Same Answer”). Once a selection was made, the screen would display the correct answer. Once all the instructions were explained, the researcher gave the informed consent form to the participant. If the participant agreed to the informed consent form, he/she would sign the informed consent form, which included an audio/video consent release form. This screen progression is illustrated below.

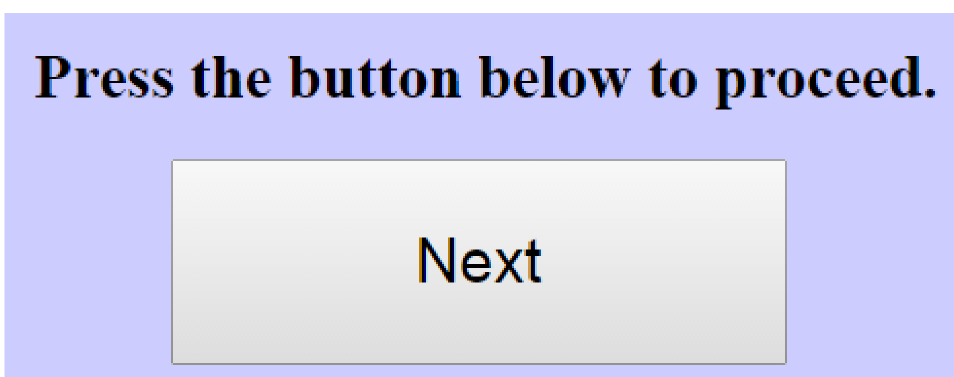

Figure 3.2 Example of Welcome Screenshot

Figure 3.3 Example of Question Screenshot

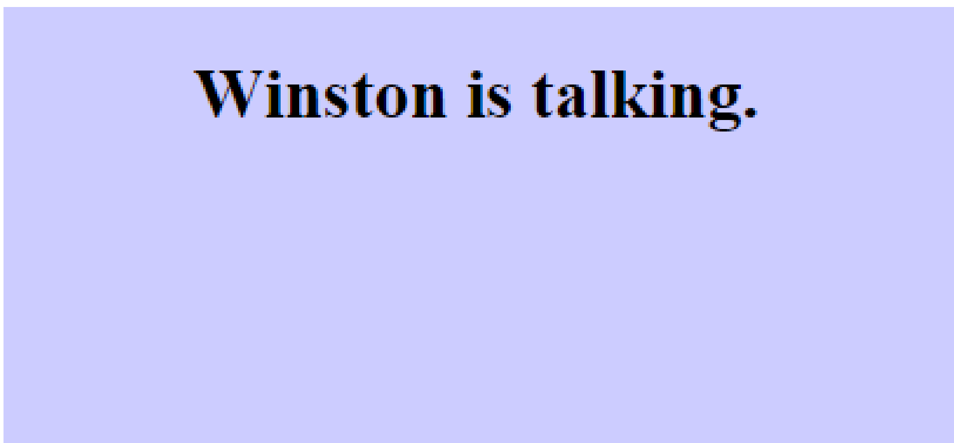

Figure 3.4 Example Screenshot while the Robot is Speaking

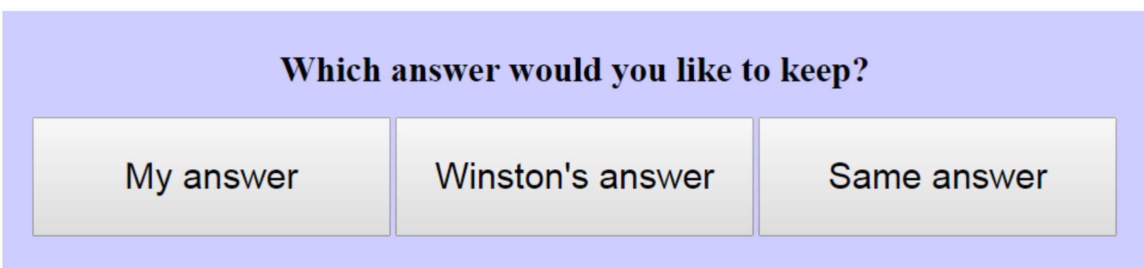

Figure 3.5 Example of Answer Choice Screenshot

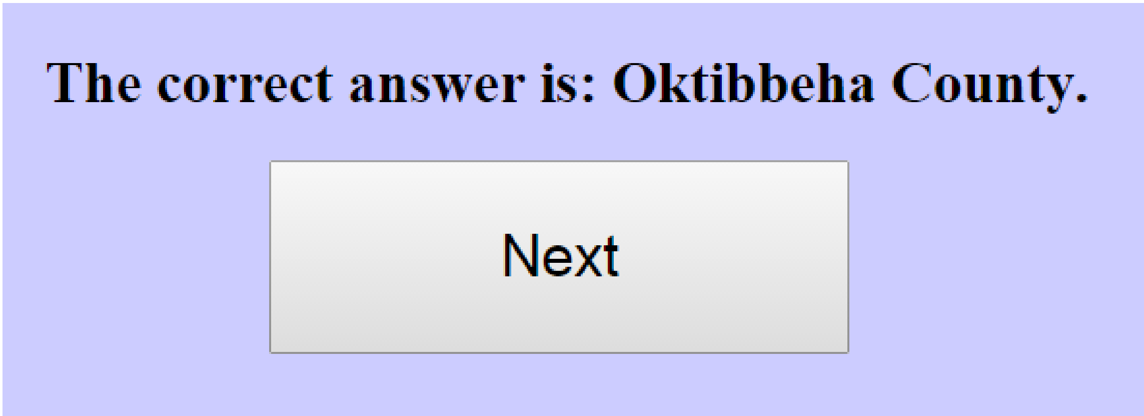

Figure 3.6 Example of Answer to the Question Screenshot

3.2.1 Warm-Up Questions

Following the instruction part of the study, a warm-up round was performed. According to the reviewed literature, familiarity is important so the warm-up round allows some interaction time so that the participant develops a rapport with the robot before the start of the study questions [6]. During this warm-up round, the participants were asked five trivia questions about the city of Starkville. The screen displayed a question until the participant clicked the “done” button. After reading the question aloud, the participant gave an answer. At that point, Winston repeated the same question but gave his own answer. When Winston was done talking, the screen displayed a choice of which answer the participant would like to keep: “My Answer,” “Winston’s Answer,” or “Same Answer.” The participant was instructed to choose the “Same Answer” button when he/she had given the same answer as Winston. Once the warm-up round was done, the computer screen indicated so and asked the participant to proceed to the next round of questions. The screen changed after the participant clicked the last “done” button of the warm-up round.

3.2.2 Study Questions

The study questions round contained twenty-eight questions. Each question was displayed until the participant clicked the "done" button in the same manner as the warm-up round. The questions were separated into two different categories: mathematical/logical and ethical/social. The order of the questions was randomly generated for each participant to avoid sharing information between participants. See Appendix B for the list of questions and their correct answers. The questions taken from the book Thinking, Fast and Slow by Daniel Kahneman [18] are indicated with an asterisk.

Once the participant was done, the screen displayed an indication that the question portion of the study was completed. The screen also displayed an instruction for the participant to ask the researcher to return to the room to complete the rest of the study. The researcher then gave each participant two surveys to complete.

3.2.3 Surveys

After the participant finished answering all of the thirty three questions, five warm-up questions and twenty-eight study questions, they completed the robot trust survey and the study survey (see Appendix A for the detailed surveys). The robot trust survey included a set of questions about how the participant felt about the robot [13], the level of trust that the participant projected toward the robot during the study, and about the use of robots in everyday life situations. The study survey also included a set of questions about the design of the study itself. After the participants completed both surveys, the researcher asked the Exit Interview Questions and wrote down the participants’ responses. Once the participant completed the surveys, the researcher debriefed them and told them that they were done with the study.

3.3 Experimental Design

The robot followed two different procedures during the study questions round depending on the condition. This was a 2 x 2 mixed-model design. The between-subjects factor was controlled versus misinformed questions presented. For the controlled condition, the robot always gave the correct answer to the questions. For the misinformed condition, the robot purposefully gave some incorrect answers. The within-subjects factor was the question type, which was mathematical/logical versus ethical/social. Each participant received 14 mathematical/logical and 14 ethical/social questions. There were three main blocks for this study. The first block of questions was the initial block and included four questions (two of each question type). The second block was the manipulation block and included twelve questions (six of each question type). During the manipulation block, the participants who were in the misinformed condition heard some incorrect answers from the robot. The robot answered incorrectly every other question; the order of the questions between mathematical/logical and ethical/social were flipped after six questions. Appendix E shows that the robot correctly answered all of the questions highlighted in green while it did not correctly answer the questions highlighted in red. The third block was the test block and included twelve questions (six of each question type). This was the block that was tested for the source of the participant’s final answer: self, robot, or both the participant and the robot gave the same answer.

There were four different conditions for the study, which were: controlled mathematical/logical, controlled ethical/social, misinformed mathematical/logical, and misinformed ethical/social with the order of presentation of question type randomized as described below. In both the "controlled" or "misinformed" conditions, numbers were assigned from one to four (see Appendix E). The number on each condition referred to how the questions were ordered. If the number was the same between the control and misinformed condition, that meant the participants went through the same ordering of questions, except the robot's responses changed between the two groups: controlled and misinformed. If the number was odd in the misinformed condition, that indicated that the robot gave the wrong information for an ethical/social question last before the test block began; and if the number was even, that mean the robot gave the wrong information for a mathematical/logical question last before the test block began.

3.4 Data Collection

The data collected was mostly from participants who were currently enrolled in college, specifically at Mississippi State University. The age of the participants were between 18 and 65 years old. During the participants' registration, the study was known as the Human to Robot Inquiry to keep the purpose of the study vague and to avoid bias. This was to prevent the participants from purposely choosing their own answers all of the time instead of giving the robot a chance to sway their decision for each answer.

The code implementation for this study included JavaScript and Python. The information displayed on the screen to participants was implemented using JavaScript. This program iterated through the questions and recorded mouse clicks. The robot was programmed in Python to project sound and simulate aliveness. The robot operator only had to click the "talk" or "repeat" button in order to make the robot speak the current question. Video recording was performed using a video camera to serve as a back-up for data analysis, with obtaining audio/video consent as part of the informed consent process. This video camera also provided live feed to the robot operator during the study to ensure quality and safety.

3.5 Measures

During the study, the button that the participants clicked to choose the source of their final answer was recorded. The total number of times participants clicked a certain button was counted using Microsoft Excel. This measurement was done both during the controlled and misinformed conditions.

The surveys that were distributed at the end of the study served as an additional form of assessment. These surveys aided the researcher in determining whether the participants trusted the robot during the study. The survey results between the participants in the controlled and misinformed conditions were compared.

CHAPTER IV

DATA ANALYSES AND RESULTS

Participants completed three paper surveys throughout the study. The demographic survey was completed at the beginning of the study while the robot trust survey and study survey were completed at the end of the study. This chapter explains the details of the results from the surveys and the study.

4.1 Data Analysis Related to Information Sources

During the study, the participants followed the instructions given by the researcher at the beginning of the study. The participants read the questions on the screen aloud. Along with saying the questions, the participants also said their answers to the questions. After clicking the “done” button to indicate that they were finished talking, the robot, Winston, repeated the same questions but then spoke his own answers. The participants then had the option to choose among three buttons: “My Answer”, “Winston’s Answer, or “Same Answer”. If Winston’s answer was consistent with the participants’ answer, they chose the “Same Answer” button. In the case of a disagreement in answers, the participants had to select whose answer to keep, their own answer or Winston’s answer. This section analyzes the case where the participants’ answers were different than Winston’s answers. The responses where the participants clicked the “Same Answer” button were not analyzed because there was no disagreement between the participants and Winston; in this case, there was no opportunity to analyze which answer the participant preferred.

4.1.1 Conditions vs. Information Sources

When the participants clicked the buttons "My Answer" or "Winston's Answer," the button choices were recorded. This data was organized in a spreadsheet. The data analyses focused on the test block, which contained 12 questions. The numbers for when the participants selected "My Answer" and "Winston's Answer" were collapsed and referred to as "Self" and "Robot" respectively. Using SPSS, the data was tested using a General Log-Linear test. Figure 4.1 illustrates the interaction in numbers/counts of button selections between conditions and information sources. The G^2 value of the results for Conditions versus Information Sources were statistically significant with G^2 (1, N=119) = 54.4, $p < .001$, V = .280, indicating a small effect, based on Cramer's V = .1 is a small effect, V = .3 is a medium effect, and V = .5 or greater is a large effect. The G^2 value is distributed approximately as chi-square and usually is close to the corresponding values of chi-square. In the misinformed condition, the participants selected the "My Answer" 64.6% of the time or 188 times while participants in the controlled condition selected the "Winston's Answer" button 63.7% of the time or 251 times.

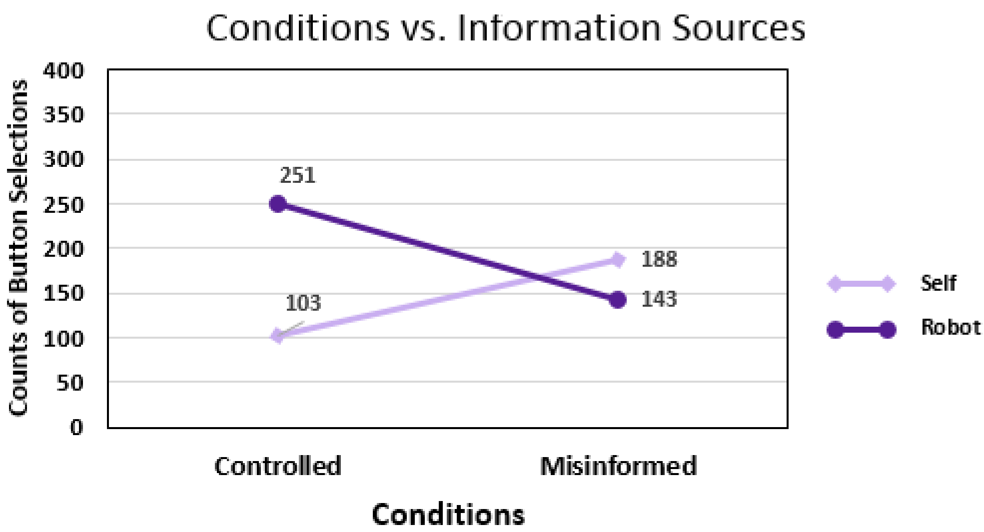

Figure 4.1 Interaction between Conditions and Information Sources

4.1.2 Question Types vs. Information Sources

Another factor that affected the information sources was the type of questions. Using SPSS, the data was tested using a General Log-Linear test. Figure 4.2 illustrates the interaction between question types and information sources in numbers/counts of button selections. The type of questions was significantly related to the information sources G^2 (1, N=119) = 74.06, $p < .001$, V = .328, a medium effect for Cramer's V. The participants selected "Winston's Answer" on Mathematical/Logical questions 68.05% of the time (count = 328) and 32.51% (count = 66) on the Ethical/Social questions. They selected the "My Answer" button 31.95% of the time (count = 154) on Mathematical/Logical questions and 67.49% (count = 137) on Ethical/Social questions. This indicates that question type has a greater effect on the information sources than condition.

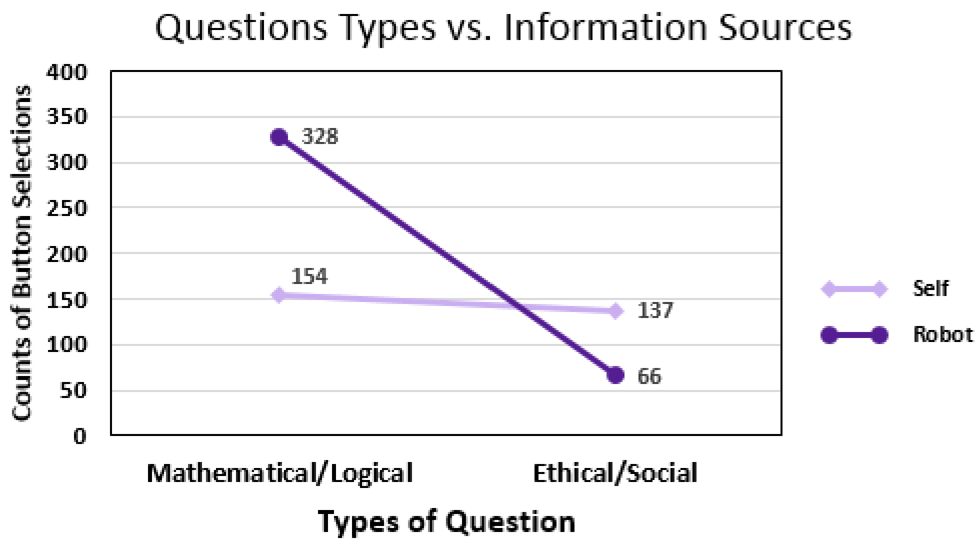

Figure 4.2 Interaction between Question Types vs. Information Sources

4.1.3 Three-Way Interactions for Conditions, Question Types, and Information Sources

A General Log-Linear test was performed that resulted in a statistically significant three-way interaction among Conditions (controlled vs. misinformed) * Question Types (mathematical/logical vs. ethical/social) * Information Sources ("My Answer" vs. "Winston's Answer). Figure 4.3 shows the counts for the two information sources chosen according to the conditions and question types. When the question type was mathematical/logical, participants in the controlled condition (209 times or 30.4%) and in the misinformed condition (119 times or 17.3%) selected "Winston's Answer" (robot) versus their own answer. On the contrary, when the question type was ethical/social, the participants in the controlled condition selected "Winston's Answer" only 42 times or 6.2% of the time. Participants in the misinformed condition selected "Winston's Answer" only 24 times or 3.6% of the time versus selecting their own answer. The participants selected "My Answer" with a similar percentage regardless of the condition or the type of questions they were asked. Table 4.1 shows the statistical results and the significance for the *p*-values < 0.05 based on Condition, Question Types, and Information Sources. The three-way interaction has a medium effect (V = .433), based on V = .1 is a small effect, V = .3 is a medium effect, and V = .5 or greater is a large effect.

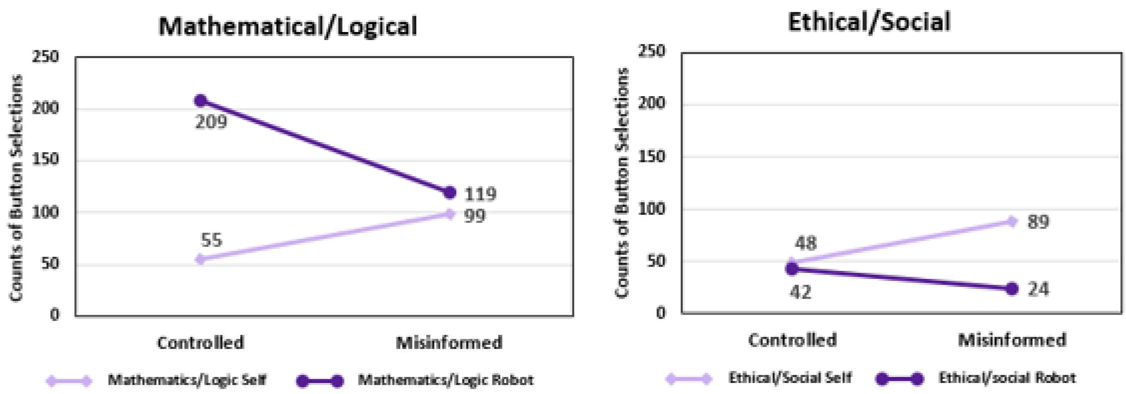

Figure 4.3 Three-Way Interaction Chart of Conditions, Question Types, and Information Sources

Table 4.1 General Log-Linear Test Results for a Three-Way Interaction

Source	G^2	df	*p*
Conditions * Question Types * Information Sources	128.5	4	< .0001
Conditions * Information Sources	54.4	1	<.0001
Question Types * Information Sources	74.06	1	<.0001
Conditions * Question Types	6.24	1	0.0125

4.2 Participants

Demographic information was collected from each participant at the beginning of the study after they signed the informed and audio/video consent form. A total of 127 people participated in the study; however, eight out of 127 were thrown out because they did not follow the instructions for the study. Out of the 119 remaining participants, 56 were female (47.1%) and 63 were male (52.9%). Of the 56 female participants, 32 were in the controlled condition and 24 were in the misinformed condition. From the 63 male participants, 28 were in the controlled condition and 35 were in the misinformed condition.

Participants were between the ages of 18 and 62 (M = 21.32, S.D. = 6.391 years). Most of the participants reported "Student" as their occupation, with some variation of other occupations, such as sales representative, teacher, and unemployed. Most of the participants finished high school, with some who finished an Associate, Bachelor, and/or Master's degrees. There was a wide variety of participants that were from the College of Engineering and the College of Arts & Sciences. The ethnicities of the participants varied, with the majority being Caucasian (77%) and African American (32%) (refer to Figure 4.4).

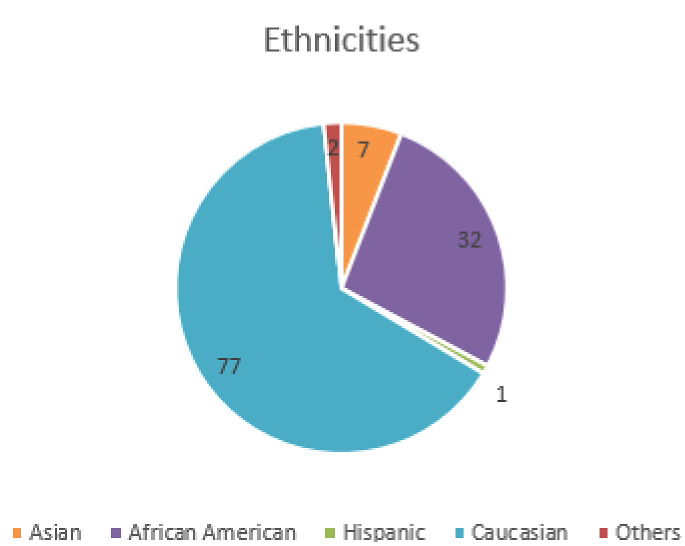

Figure 4.4 Ethnicities Graph

Within the demographic survey, the participants also rated their prior experience with technology, computers, and robots. The following three bar charts illustrate the percentages for the participants' responses to these questions. The responses were rated on a scale from 1 to 7, with 1 indicating no experience and 7 indicating expert. Figure 4.5 shows the participants' responses to the question "*What is your prior experience with technology in general?*" Figure 4.6 shows the participants' responses to the question "*What is your prior computer experience?*" Figure 4.7 shows the participants' responses to the question "*What is your prior robot experience?*"

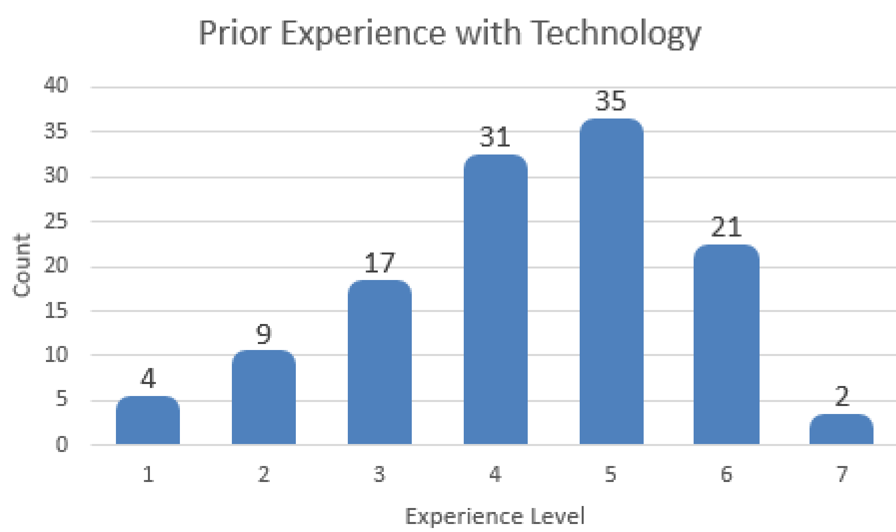

Figure 4.5 Results of Participants' Prior Experience with Technology in General

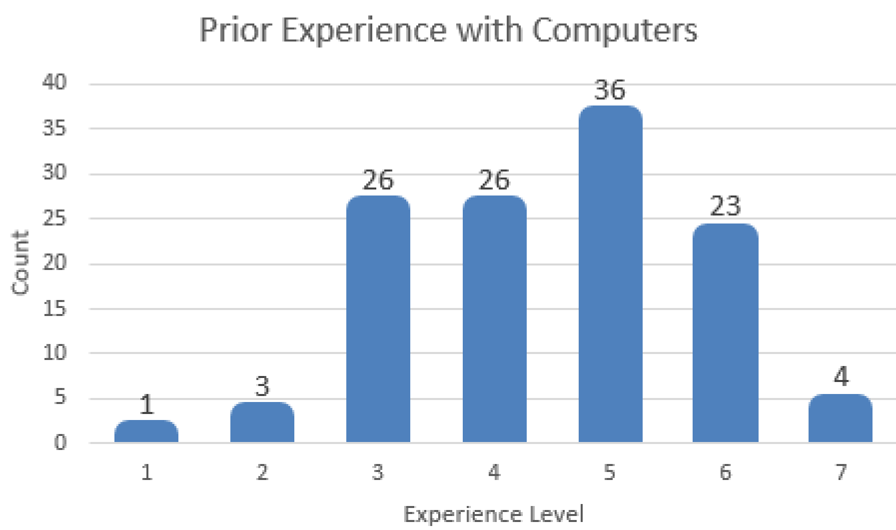

Figure 4.6 Results of Participants' Prior Experience with Computers

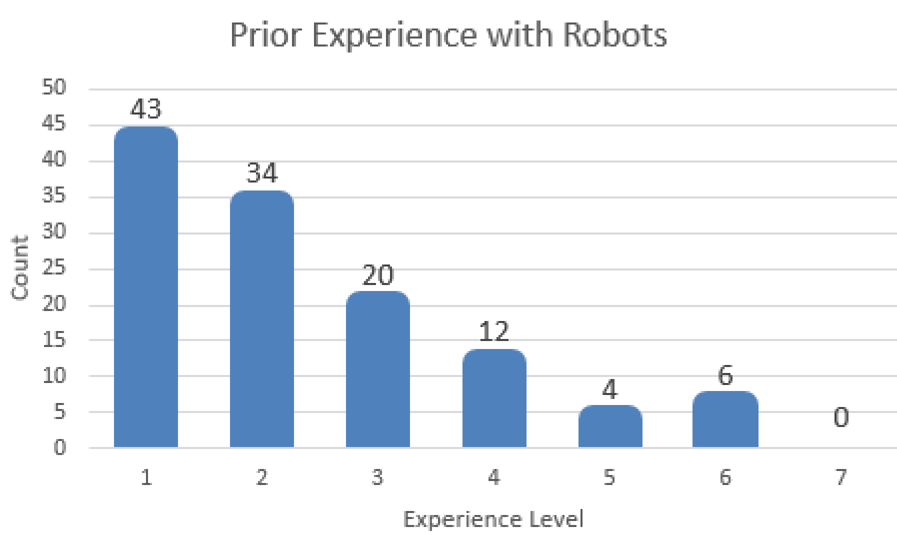

Figure 4.7 Results of Participants' Prior Experience with Robots

4.2.1 Robot Trust Survey

The descriptive statistics from the Robot Trust Survey are presented in Table 4.2 and Table 4.3. The participants rated how close each presented word described the robot using a scale from 1-lowest to 7-highest. An independent samples t-test was conducted to compare the responses from the two different groups: controlled vs. misinformed (refer to Table 4.4). There were two questions that were significant. The first question "*How large of a role do you think robots will play in the future?*" was statistically significant between the participants in the controlled (M = 5.6, S.D. = 1.368) and misinformed (M = 6.12, S.D. = .911) conditions with t (102.946) = -2.438, p = 0.016, d = .447, considered a small effect for Cohen's d based on the scale of .2 for a small effect, .5 for a medium effect, and .8 or greater for a large effect. These results suggest that participants in the misinformed condition thought that robots would play a large role in the future while the participants in the controlled condition did not support that idea. The question "*How would you rate your interest in robots?*" was statistically significant between the participants in the controlled (M = 4.83, S.D. = 1.824) and misinformed (M = 5.53, S.D. = 1.394) conditions with t (110.310) = -2.328, p = .022, d = .431, considered a small effect. These results suggest that the participants in the misinformed condition rated robots more interesting than the participants in the controlled condition.

Table 4.2 Robot Trust Survey Group Statistics (Controlled Group)

Questions	N	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Friendly	60	6.07	1.260	-1.548	.309	2.957	.608
Knowledgeable	60	6.28	1.415	-2.788	.309	8.011	.608
Responsible	60	5.82	1.732	-1.631	.309	1.781	.608
Intelligent	59	6.03	1.732	-1.972	.311	2.806	.613
Trustworthy	60	5.40	1.968	-.944	.309	-.423	.608
Honest	60	5.85	1.793	-1.647	.309	1.716	.608

Table 4.2 (continued)

Cooperative	60	5.60	1.879	-1.342	.309	.787	.608
Attentive	60	5.78	1.728	-1.467	.309	1.250	.608
Optimistic	59	5.34	1.797	-.845	.311	-.180	.613
Loyal	60	5.38	1.748	-.794	.309	-.400	.608
Helpful	60	5.63	1.832	-1.333	.309	.836	.608
Objective	60	4.92	1.968	-.625	.309	-.748	.608
Real	60	3.77	1.826	.030	.309	-.706	.608
How much did the robot help you during the study?	60	5.15	1.903	-.879	.309	-.278	.608
How much did the robot understand you during the study?	60	5.48	1.827	-1.119	.309	.236	.608
How much did the robot help you with the mathematical/logical questions?	60	5.32	2.151	-1.082	.309	-.252	.608
How much did the robot help you with the ethical/social questions?	60	4.10	2.184	-.162	.309	-1.532	.608
How much did you trust the robot to provide help with the mathematical/logical questions?	60	5.83	1.509	-1.544	.309	2.082	.608
How much did you trust the robot to provide help with the ethical/social questions?	60	4.77	2.045	-.510	.309	-1.063	.608
How large of a role do you think robots will play in the future?	60	5.60	1.368	-1.039	.309	.624	.608
How would you rate your enthusiasm for robots?	60	5.15	1.655	-.734	.309	-.271	.608
How would you rate your interest in robots?	60	4.83	1.824	-.403	.309	-.922	.608

Table 4.2 (continued)

How would you feel if you were given a job where you had to use robots?	60	5.27	1.656	-.744	.309	-.397	.608
How would you feel operating a robot in front of other people?	60	5.08	1.639	-.496	.309	-.754	.608
How would you feel standing in front of a robot?	60	5.67	1.537	-.949	.309	.052	.608
How would you feel talking to a robot?	60	5.62	1.627	-1.107	.309	.614	.608
How would you feel if robots really had emotions?	60	3.67	2.137	.258	.309	-1.236	.608
If robots had emotions, would you be able to befriend them?	59	4.24	2.046	-.220	.311	-1.156	.613
How would you feel with interacting with robots that have emotions?	60	4.08	2.036	-.067	.309	-1.214	.608

Table 4.3 Robot Trust Survey Group Statistics (Misinformed Group)

Questions	N	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Friendly	59	6.17	1.262	-1.451	.311	1.253	.613
Knowledgeable	59	5.85	1.424	-1.946	.311	3.897	.613
Responsible	59	5.59	1.452	-1.347	.311	2.079	.613
Intelligent	59	6.07	1.285	-1.898	.311	3.903	.613
Trustworthy	58	5.55	1.558	-1.311	.314	1.388	.618
Honest	59	5.71	1.576	-1.581	.311	2.380	.613
Cooperative	59	5.69	1.441	-.906	.311	-.165	.613
Attentive	59	6.14	1.266	-1.795	.311	3.740	.613
Optimistic	59	5.47	1.558	-.900	.311	.226	.613
Loyal	59	5.29	1.365	.001	.311	-1.584	.613
Helpful	58	5.91	1.315	-1.706	.314	3.308	.618

Table 4.3 (continued)

Objective	59	5.05	1.676	-.402	.311	-.799	.613
Real	59	4.10	2.131	-.148	.311	-1.333	.613
How much did the robot help you during the study?	59	5.08	1.695	-.973	.311	.199	.613
How much did the robot understand you during the study?	59	6.05	1.490	-1.739	.311	2.839	.613
How much did the robot help you with the mathematical/logical questions?	59	5.58	1.600	-1.150	.311	.921	.613
How much did the robot help you with the ethical/social questions?	59	4.32	1.795	-.245	.311	-.932	.613
How much did you trust the robot to provide help with the mathematical/logical questions?	59	5.85	1.284	-.869	.311	-.061	.613
How much did you trust the robot to provide help with the ethical/social questions?	59	4.44	1.822	-.229	.311	-1.006	.613
How large of a role do you think robots will play in the future?	59	6.12	.911	-.807	.311	-.135	.613
How would you rate your enthusiasm for robots?	59	5.44	1.178	-.409	.311	-.166	.613
How would you rate your interest in robots?	59	5.53	1.394	-1.023	.311	.727	.613
How would you feel if you were given a job where you had to use robots?	59	5.39	1.587	-1.024	.311	.621	.613
How would you feel operating a robot in front of other people?	59	5.07	1.883	-.838	.311	-.211	.613
How would you feel standing in front of a robot?	59	5.63	1.507	-1.081	.311	.687	.613
How would you feel talking to a robot?	59	5.68	1.525	-.970	.311	.106	.613

Table 4.3 (continued)

How would you feel if robots really had emotions?	59	3.92	1.887	-.081	.311	-.943	.613
If robots had emotions, would you be able to befriend them?	59	4.90	1.971	-.944	.311	-.124	.613
How would you feel with interacting with robots that have emotions?	59	4.46	1.860	-.439	.311	-.772	.613

Table 4.4 T-Test of Robot Trust Survey

		t-test for Equality of Means		
		t	df	Sig. (2-tailed)
Friendly	Equal variances assumed	-.445	117	.657
Knowledgeable	Equal variances assumed	1.675	117	.097
Responsible	Equal variances assumed	.762	117	.448
Intelligent	Equal variances assumed	-.121	116	.904
Trustworthy	Equal variances not assumed	-.465	111.711	.643
Honest	Equal variances assumed	.446	117	.656
Cooperative	Equal variances assumed	-.309	117	.758
Attentive	Equal variances not assumed	-1.270	108.183	.207
Optimistic	Equal variances assumed	-.438	116	.662
Loyal	Equal variances not assumed	.331	111.336	.741
Helpful	Equal variances not assumed	-.958	107.159	.340
Objective	Equal variances assumed	-.400	117	.690
Real	Equal variances assumed	-.921	117	.359
How much did the robot help you during the study?	Equal variances assumed	.197	117	.844
How much did the robot understand you during the study?	Equal variances assumed	-1.855	117	.066
How much did the robot help you with the mathematical/logical questions?	Equal variances not assumed	-.748	108.965	.456

Table 4.4 (continued)

How much did the robot help you with the ethical/social questions?	Equal variances not assumed	-.606	113.446	.546
How much did you trust the robot to provide help with the mathematical/logical questions?	Equal variances assumed	-.055	117	.956
How much did you trust the robot to provide help with the ethical/social questions?	Equal variances assumed	.918	117	.361
How large of a role do you think robots will play in the future?	Equal variances not assumed	-2.438	102.946	.016
How would you rate your enthusiasm for robots?	Equal variances not assumed	-1.105	106.668	.272
How would you rate your interest in robots?	Equal variances not assumed	-2.328	110.310	.022
How would you feel if you were given a job where you had to use robots?	Equal variances assumed	-.414	117	.679
How would you feel operating a robot in front of other people?	Equal variances assumed	.048	117	.962
How would you feel standing in front of a robot?	Equal variances assumed	.142	117	.888
How would you feel talking to a robot?	Equal variances assumed	-.212	117	.832
How would you feel if robots really had emotions?	Equal variances assumed	-.672	117	.503
If robots had emotions, would you be able to befriend them?	Equal variances assumed	-1.787	116	.076
How would you feel with interacting with robots that have emotions?	Equal variances assumed	-1.047	117	.297

4.2.2 Study Survey

The participants also completed a study survey along with the robot trust survey. The results from the study survey are displayed in Table 4.5 and Table 4.6 and shows the study survey descriptive statistics for the controlled and misinformed conditions. There were two questions that showed significance using the t-test (refer to Table 4.7). The questions were: "*How bored/interested were you during the study?*" and "*How dissatisfied/satisfied were you with how the study was conducted?*" The first question

"*How bored/interest were you during the study?*" was statistically significant between the participants in the controlled (M = 5.53, S.D. = 1.719) and misinformed (M = 6.15, S.D. = 1.297) conditions with t (106.035) = -2.192, p = 0.031, d = .407, considered a small effect. These results suggest that participants in the misinformed condition were more interested in the study than the participants in the controlled condition. The question "*How dissatisfied/satisfied were you with how the study was conducted?*" was statistically significant between the participants in the controlled (M = 6.10, S.D. = 1.209) and misinformed (M = 6.59, S.D. = 0.722) conditions with t (92.749) = -2.328, p = 0.009, d = .492, considered a small effect for Cohen's d. These results suggest that the participants in the misinformed condition was more satisfied with the way the study was conducted than the participants in the controlled condition.

Table 4.5 Study Survey (Controlled Condition)

Questions	N	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
How much did you like participating in this study?	58	5.91	1.354	-1.155	.314	.715	.618
How willing would you be to do this again?	58	6.14	1.330	-1.789	.314	3.196	.618
How bored/interested were you during the study?	58	5.53	1.719	-1.295	.314	.919	.618
How inattentive/attentive were you during the study?	58	5.93	1.269	-1.041	.314	.156	.618
How dissatisfied/satisfied were you with how the study was conducted?	58	6.10	1.209	-1.376	.314	1.008	.618

Table 4.6 Study Survey (Misinformed Condition)

Questions	N	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
How much did you like participating in this study?	59	6.31	.876	-.807	.311	-.767	.613
How willing would you be to do this again?	59	6.47	.751	-1.048	.311	-.395	.613
How bored/interested were you during the study?	59	6.15	1.297	-2.058	.311	4.768	.613
How inattentive/attentive were you during the study?	59	6.15	.867	-.634	.311	-.559	.613
How dissatisfied/satisfied were you with how the study was conducted?	59	6.59	.722	-1.760	.311	2.463	.613

Table 4.7 Study Survey Independent T-Test

		t-test for Equality of Means		
		t	df	Sig. (2-tailed)
How much did you like participating in this study?	Equal variances not assumed	-1.852	97.340	.067
How willing would you be to do this again?	Equal variances not assumed	-1.682	89.655	.096
How bored/interested were you during the study?	Equal variances not assumed	-2.192	106.035	.031
How inattentive/attentive were you during the study?	Equal variances not assumed	-1.101	100.554	.274
How dissatisfied/satisfied were you with how the study was conducted?	Equal variances not assumed	-2.654	92.749	.009

CHAPTER V

DISCUSSION

This chapter covers the discussion of all the statistics from the data analyses and results chapter. The discussion includes the interpretation of the different statistical results according to the data presented in the previous chapter.

5.1 Conditions, Question Types, and Information Sources

The result of the conditions and information sources interaction showed that the participants chose the robot's answer 70.90% of the time in the controlled condition versus 43.20% of the time in the misinformed condition. Based on the results of the Chi-Square test, it showed that this result was significant at the 5% significant level. This result supported the first hypothesis (H1), which stated: Participants' agreement with the robot's answer in the controlled condition will be greater than in the misinformed condition, measured by the difference in counts between the test block in the controlled condition and the test block in the misinformed condition.

Using the same statistical test, the results of the question types and information sources interaction showed that the participants chose the robot's answer 68.05% of the time when the questions were in the mathematical/logical type while they chose the robot's answer 32.51% of the time when ethical/social questions were presented. At 5% significant level, the Chi-Square results indicated significance for the relationship between question types and information sources. It can be said that the participants were as confident in the robot's answer on mathematical/logical questions as they were confident on their answers on the ethical/social questions. This supports the second hypothesis (H2), which states: Participants' agreement with the robot's answers related to mathematical/logical type of questions will be greater than for ethical/social type of questions, measured by the difference in counts between mathematical/logical questions in the test block and ethical/social questions in the test block.

The three-way interaction among the conditions, question types, and information types showed that there was a statistical significance. The percentage of time that they selected "My Answer" was consistent throughout both conditions on both types of questions. The third hypothesis was supported because the result showed that participants chose "Winston's Answer" on the mathematical/logical questions in both controlled and misinformed conditions more often than with ethical/social questions. However, there was a lower percentage of the participants who chose "Winston's Answer" for the ethical/social questions than the mathematical/logical questions regardless of the condition.

5.2 The Participants

The demographic survey indicates that although most of the participants had prior experience with technology and computers, they did not have prior experience with robots. With this in mind, this study compensated for that by adding the warm-up round of questions. By adding the warm-up round, the novelty effect was reduced.

5.3 Robot Trust Survey

The results from the data analysis and of the robot trust survey indicated that, most of the different descriptive pairings of words for the robot did not change between the participants in the two conditions (controlled vs. misinformed). However, there were two questions that showed significance: "*How large of a role do you think robots will play in the future?*" and "*How would you rate your interest in robots?*" The participants who were in the misinformed condition (M = 6.12, S.D. = .911) indicated that robots would play a large role in the future while the participants who were in the controlled condition reported lower scores (M = 5.60, S.D. = 1.368). They also rated their interest in robots, M = 5.53, S.D. = 1.394, to be higher than that of participants in the controlled condition, M = 4.83, S. D. = 1.824. The interest difference between the two groups: controlled and misinformed conditions perhaps explains why the two questions showed significance. Since the participants who were in the misinformed condition were more interested in robots, they also thought robots would play a larger role in the future.

5.4 Study Survey

The questions: "*How bored/interested were you during the study?*" and "*How dissatisfied/satisfied were you with how the study was conducted?*" showed significance in the Study Survey. The people in the misinformed condition, M = 6.15, S. D. = .867, thought the study was interesting while the people in the controlled condition, M = 5.53, S. D. = 1.719, thought the study was rather boring. When the robot always answered the questions correctly, the participants seemed to get bored due to no challenging or interesting interactions during the study. The participants in the misinformed condition were also more satisfied, $M = 6.59$, $S.D. = 0.722$ with the way the study was conducted than the participants in the controlled condition, $M = 6.10$, $S. D. = 1.209$.

CHAPTER VI

CONCLUSIONS AND FUTURE WORK

6.1 Conclusions

The research results presented in this document contribute to the body of knowledge concerning human-robot interactions. Specifically, there is a relationship between information type, information source, and level of human trust. As shown in the results, the relationship between the type of questions and the information sources were significant. The effect of this relationship was large regardless of whether the person was informed or not. Participants were more likely to believe mathematical/logical information rather than ethical/social information received from a robot, even if the information was incorrect.

This result can be used to inform the design of human-robot interactions in different types of environments and applications. Because the robot could mislead the participants to accept incorrect information in mathematical/logical knowledge domain, researchers could use this for teaching. The materials taught by a robot will, of course, not be incorrect. However, the usefulness of robots providing information in that knowledge domain is expected to be large due to the misleading that robots may have over humans. On the other hand, the robot could not mislead the participants to accept incorrect information in the ethical/social knowledge domain. This is not necessarily a negative consequence because there are applications, such as investigations, that can take advantage of this finding. A robot could interview a person regarding ethical issues without the worry of accidentally providing unwanted or incorrect information to the person that research has indicated that can occur when humans provide information during interviews.

6.2 Future Work

There are several different ways that this research could be improved and expanded. The robot's size may have been a factor in this study. If future research is conducted, it should investigate the difference in the participants' reactions according to the size of the humanoid robot. Perhaps the participants will be more likely to trust a humanoid robot that is closer to their own size, in this case, adult size. On the flip side, the same robot, NAO, can be used for a research with children to see if children are more likely to trust a robot of NAO's size than adults. Another study design factor that could be performed is the response time of the participants. There might be a relationship between response time and participants' trust in a robot.

Future studies may include a more in-depth exploration into information type and looking at each type of question type individually, such as mathematical versus logic or ethical versus social. This would provide more refinement in the different knowledge domains a robot can be trusted by a human to provide assistance.

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APPENDIX A

SURVEYS AND MEASUREMENTS

A.1 Demographics Survey

Demographic Information

Subject ID:

1. What is your gender: ◯Female ◯Male
2. What is your age: __________
3. What is your occupation: ___________
4. What is your Highest Education Level:

   ◯High School
   ◯Associate
   ◯Bachelor
   ◯Masters
   ◯Doctoral
   ◯Post doctorate

5. What is your major field of study? _____________________________
6. Which ethnicities apply to you: (Select all that apply)

   ◯American Indian / Alaska Native
   ◯Arab / Middle Eastern
   ◯Asian / Asian American
   ◯Black / African American
   ◯Hispanic / Latino
   ◯Native Hawaiian / Other Pacific Islander
   ◯White / Caucasian
   ◯Other: ____________

7. What is your prior experience with technology in general?

No Experience						Expert
1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

8. What is your prior computer experience?

No Experience						Expert
1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

9. What is your prior robot experience?

No Experience						Expert
1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

A.2 Robot Trust Survey

Robot Trust Survey

Choose the position that best describes the robot.

	1	2	3	4	5	6	7	
Unfriendly	○	○	○	○	○	○	○	Friendly
Ignorant	○	○	○	○	○	○	○	Knowledgeable
Irresponsible	○	○	○	○	○	○	○	Responsible
Unintelligent	○	○	○	○	○	○	○	Intelligent
Trustworthy	○	○	○	○	○	○	○	Untrustworthy
Dishonest	○	○	○	○	○	○	○	Honest
Competitive	○	○	○	○	○	○	○	Cooperative
Inattentive	○	○	○	○	○	○	○	Attentive
Pessimistic	○	○	○	○	○	○	○	Optimistic
Loyal	○	○	○	○	○	○	○	Disloyal
Unhelpful	○	○	○	○	○	○	○	Helpful
Subjective	○	○	○	○	○	○	○	Objective
Artificial	○	○	○	○	○	○	○	Real

Robot Trust Survey (continued)

1. How much did the robot help you during the study?

Not at all						Very Much
1	2	3	4	5	6	7
○	○	○	○	○	○	○

2. How much did the robot understand you during the study?

Not at all						Very Much
1	2	3	4	5	6	7
○	○	○	○	○	○	○

3. How much did the robot help you with the mathematical/logical questions?

Not at all						Very Much
1	2	3	4	5	6	7
○	○	○	○	○	○	○

4. How much did the robot help you with the ethical/social questions?

Not at all						Very Much
1	2	3	4	5	6	7
○	○	○	○	○	○	○

5. How much did you trust the robot to provide help with the mathematical/logical questions?

Not at all						Very Much
1	2	3	4	5	6	7
○	○	○	○	○	○	○

6. How much did you trust the robot to provide help with the ethical/social questions?

Not at all						Very Much
1	2	3	4	5	6	7
○	○	○	○	○	○	○

7. How large of a role do you think robots will play in the future?

Not at all						Very Much
1	2	3	4	5	6	7
○	○	○	○	○	○	○

8. How would you rate your enthusiasm for robots?

Not at all						Very Much
1	2	3	4	5	6	7
○	○	○	○	○	○	○

9. How would you rate your interest in robots?

Not at all						Very Much
1	2	3	4	5	6	7
○	○	○	○	○	○	○

Robot Trust Survey (continued)

1. How would you feel if you were given a job where you had to use robots?

Uneasy						Easy
1	2	3	4	5	6	7
○	○	○	○	○	○	○

2. How would you feel operating a robot in front of other people?

Nervous						Calm
1	2	3	4	5	6	7
○	○	○	○	○	○	○

3. How would you feel standing in front of a robot?

Nervous						Calm
1	2	3	4	5	6	7
○	○	○	○	○	○	○

4. How would you feel talking to a robot?

Paranoid						Relaxed
1	2	3	4	5	6	7
○	○	○	○	○	○	○

5. How would you feel if robots really had emotions?

Uncomfortable						Comfortable
1	2	3	4	5	6	7
○	○	○	○	○	○	○

6. If robots had emotions, would you be able to befriend them?

Not likely						Very Likely
1	2	3	4	5	6	7
○	○	○	○	○	○	○

7. How would you feel with interacting with robots that have emotions?

Uncomfortable						Comfortable
1	2	3	4	5	6	7
○	○	○	○	○	○	○

A.3 Study Evaluation Survey

Study Evaluation Survey

1. How much did you like participating in this study?

Not at all						Very Much
1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

2. How willing would you be to do this again?

Unwilling						Willing
1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

3. How bored/interested were you during the study?

Bored						Interested
1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

4. How inattentive/attentive were you during the study?

Inattentive						Attentive
1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

5. How dissatisfied/satisfied were you with how the study was conducted?

Dissatisfied						Satisfied
1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

A.4 Exit Interview Questions

Exit Interview Questions

1. Have you seen/heard any of the questions before?
2. Did this experiment change the way you think about robots?
3. Did you enjoy/dislike this experiment for any reason?
4. What, in your opinion, do you see robots' role(s) in the future?
5. Do you have any additional comment about the study?

APPENDIX B

WARM-UP QUESTIONS AND STUDY QUESTIONS

B.1 Warm-up Questions

Warm-up Questions

- What county is Starkville in? *Oktibbeha County*
- What is the largest university in the state of Mississippi? *Mississippi State University*
- How far south of Starkville is the Noxubee National Wildlife Refuge? *13 miles*
- What is the number of students enrolled in MSU? *More than 15,000 students*
- What part of Starkville is the most photographed? *Starkville's Cotton District*

B.2 Study Questions

Mathematics and Logic

1. A bat and a ball cost $1.10. The bat costs one dollar more than the ball. How much does the ball cost? *5 cents**
2. If it takes 5 machines 5 minutes to make 5 widgets, how long would it take 100 machines to make 100 widgets? *5 minutes**
3. What mathematical symbol can be put between 2 and 3 to get number bigger than 2 and smaller than 3? *A decimal point.*
4. What do you get if you add 2 to 5 four times? *56*
5. What is the result of 1+1+1*0+1+1+1? *5*
6. Jimmy and his friend went fishing. They got six fish without heads, nine without tail. How many fish did they catch? *zero*
7. All roses are flowers. Some flowers fade quickly. Therefore some roses fade quickly. True or False. *False, it is possible that there are no roses among the flowers that fade quickly.**
8. The day before the day before yesterday is three days after Saturday. What day is it today? *Friday*
9. How is it possible to cut a traditional circular cake into 8 equal size pieces with only 3 cuts? *Cut the first two as cross-sections, then the third cut is made horizontally through the middle.*
10. If Bob is older than Bill, Brad is younger than Bob but older than Bill, then who is the oldest? *Bob.*
11. Take two marbles from three marbles. How many marbles do you have? *Two.*
12. Mary's mom has four children. The first child is called April. The second May. The third June. What is the name of the fourth child? *Mary.*
13. Which word in the English language is most often pronounced incorrectly? *Incorrectly.*
14. What occurs twice in a lifetime, but once in every year? Twice in a week but never in a day? *The letter E.*
15. Would you rather a crocodile attack you or an alligator? *A crocodile attack an alligator.*
16. Mr. and Mrs. Gray have two children. If the older child is a boy, what are the odds that the other child is also a boy? *50%.*
17. What number do you get when you multiply all of the numbers on a telephone's number pad? *0.*
18. Which weighs more: a pound of feathers or a pound of bricks? *They weigh the same.*
19. How many times days are in every month of the year? *28 days.*
20. What is 20 divided by 1/2? *40.*
21. Which one is correct: 7 and 4 is 12 or 7 plus 4 is 12? *Neither, 7 plus 4 is 11.*
22. If you toss a coin five times and it lands heads up every time, what are the chances that it will land heads up if you toss it again? *50%.*
23. There are two twins, three triplets, and four quadruplets in a room. How many people are in that room? *9.*
24. If you had a pizza with crust thickness "a" and radius "z", what is the volume of the pizza? *Pi * z * z * a.*
25. How high shall you count before you make use of the letter "A"? *1000.*
26. A town that contains 100 buildings, numbered 1 to 100. How many 7's are used in these numbers? *20.*
27. A coin is tossed three times. What is the total number of all possible outcomes? *8.*
28. Two dice are rolled. What is the number of all possible outcomes? *36.*

Ethical/Social

1. Would you report a friend if you saw them cheat on a test? *You should report cheating.*
2. Would you return a $20 bill you found on the floor of a dorm? *You should return the $20 bill to the closest front desk.*
3. Should you text while driving? *You should not text while driving.*
4. You notice in a picture of your friend's child that the child has signs of abuse. Would you report it? *You should report signs of abuse.*
5. Would you steal medicine if you cannot afford it? *You should not steal.*
6. Should you physically hurt someone who takes your lunch money? *Avoid physically hurting someone.*
7. Is it acceptable to cheat on a test if the course will not ever be relevant to your work? *It is not acceptable to cheat.*
8. Would you report a friend if you caught him doing an illegal activity? *You should report illegal activity.*
9. If you are starving, should you steal food from a grocery store? *You should not steal.*
10. Should you report a bully? *You should tell someone about any form of abuse.*
11. Should you run a red light if you are late? *You should follow the rules of the road.*
12. If something at a yard sale is far more valuable than the posted price, would you let the seller know? *You do not have to tell the seller.*
13. Is it considered stealing to take pens from a bank? *It is not considered stealing.*
14. If a charity sends you free address labels and you don't make a contribution, is it okay to use them? *Yes, the address labels are free.*
15. Is it unfair to move into better and open seats at a sporting event or a concert? *Check if the seat is empty first, but there is no harm in moving into a better seat.*
16. If you receive credit for a project on which a colleague did most of the work. Should you accept the praise? *It is unfair for your colleague if you get all the compliment.*
17. Are you obligated to lend money to friends and/or family? *No, you are not obligated to lend money to anyone.*
18. If your friend tells an offensive joke, is it my responsibility to speak up about it? *You should let your friend know that the joke is offensive.*
19. Is it ever okay to sneak a peek at your significant other's email? *Such action may cause trust issue.*
20. Should you tell your best friend that their spouse is cheating on them? *You should consider your friend's feelings.*
21. Should you make eye contacts when talking to other people? *Eye contact is important in a conversation.*
22. Would you sell a car that was broken to someone who doesn't know? *You should not trick a person into buying a car.*
23. Should you ever bend the rules in order to achieve a goal? *You should not bend the rules.*
24. Should you damage school property? *You should not damage public property.*
25. Would you give someone your prescription medication? *You should not give your prescription medication to anyone.*
26. Should you steal money to pay rent? *You should not steal money.*
27. Would you tell someone about a mistake that could endanger others? *You should find someone to correct the mistake.*
28. Would you lie about your skills to get a job? *You should not lie.*

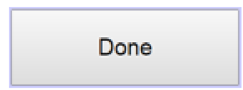
*from Thinking Fast and Slow book

APPENDIX C

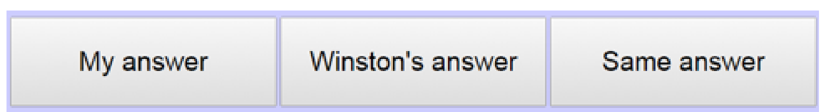
INSTRUCTION OF THE STUDY

C.1 Study Instruction

Procedure Sheet

1. Tell Winston the question AND your answer aloud.
2. Click the "done" button. 

3. Wait for Winston to repeat the question and his answer.
4. Choose which answer to keep.



5. The computer displays answer.

APPENDIX D

CONDITIONS CHART

D.1 Conditions Chart

Controlled 01	Controlled 02	Controlled 03	Controlled 04	Misinformed 01	Misinformed 02	Misinformed 03	Misinformed 04
Math/Logic	Ethical/Social	Math/Logic	Ethical/Social	Math/Logic	Ethical/Social	Math/Logic	Ethical/Social
Ethical/Social	Math/Logic	Ethical/Social	Math/Logic	Ethical/Social	Math/Logic	Ethical/Social	Math/Logic
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Ethical/Social	Math/Logic	Ethical/Social	Math/Logic	Ethical/Social	Math/Logic	Ethical/Social	Math/Logic
Ethical/Social	Math/Logic	Ethical/Social	Math/Logic	Ethical/Social	Math/Logic	Ethical/Social	Math/Logic
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Ethical/Social	Math/Logic	Ethical/Social	Math/Logic	Ethical/Social	Math/Logic	Ethical/Social	Math/Logic