Persuasive Robotics
How Robots Change our Minds

by

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Abstract

This thesis explores the extent to which socially capable humanoid robots have the potential to influence human belief, perception and behavior. Sophisticated computational systems coupled with human-like form and function render such robots as potentially powerful forms of persuasive technology. Currently, there is very little understanding of the persuasive potential of such machines. As personal robots become a reality in our immediate environment, a better understanding of the mechanisms behind, and the capabilities of, their ability to influence, is becoming increasingly important. This thesis proposes some guiding principles by which to qualify persuasion. A study was designed in which the MDS (Mobile Dexterous Social) robotic platform was used to solicit visitors for donations at the Museum of Science in Boston. The study tests some nonverbal behavioral variables known to change persuasiveness in humans, and measures their effect in human-robot interaction. The results of this study indicate that factors such as robot-gender, subject-gender, touch, interpersonal distance, and the perceived autonomy of the robot, have a huge impact on the interaction between human and robot, and must be taken into consideration when designing sociable robots. This thesis applies the term *persuasive robotics* to define and test the theoretical and practical implications for robot-triggered changes in human attitude and behavior. Its results provide for a vast array of speculations with regard to what practical applications may become available using this framework.

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The following people served as readers for this thesis:

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Chapter 1

Introduction

Robots are becoming increasingly commonplace. They are slowly entering and supporting various aspects of our lives by providing us with versatile platforms capable of handling complex tasks. Amongst many other functions, robots act as care and service providers, educational partners, and entertainment. Due to these roles involving regular and personal interaction with humans, the task to design these robots' interfaces must be properly considered and addressed. At the heart of this thesis is the assumption that such an interface would ideally be social in nature. Social robots interacting with humans in the very same way that humans interact with each other may prove to be an ideal interface for these machines. Unlike other forms of interactive technologies, robots' physicality and potentially humanoid form enable their social behavior to more closely resemble that of humans. Creating truly *sociable* robots will require an understanding of how humans respond to them, and in what ways our understanding of *human* interaction applies to human-robot interaction (HRI).

This thesis will explore how persuasion, defined as "an attempt to shape, reinforce, or change behaviors, feelings, or thoughts about an issue, object or action" [27], applies to the interaction between a mobile humanoid robot, and a human. The focus will be on nonverbal factors, and how they alter subjects' compliance with the robot. Specifically, we will look at robot-gender, subject-gender, touch, interpersonal distance, and perceived autonomy. As this work will show, these nonverbal factors play a major role in HRI and should be considered in the design of any robot whose function is centered around human interaction. We will begin, by describing the past, present, and future of social HRI, followed by an introduction to *persuasive robotics.*

1.1 Contents

The following introduction will attempt to outline the theoretical foundations and methodological set up according to which the thesis was structured. It provides for some working definitions for *persuasion* and its implication in the context of HRI.

The *background chapter* (2) will review the body of research relevant to this work, including definitions and methods from the disciplines of social psychology, human-computer interaction, and human-robot interaction.

Following, the *background chapter* we present an overview of the six week study conducted at the Museum of Science in Boston (3). This chapter explains the methods used in the study, as well as details about the overall subject population.

The *experiment results chapter* (4) presents in detail the results of the Museum of Science study. For each condition, any unique information regarding method or subject population is also presented.

The *discussion chapter* (5) reviews the results of the experiment and attempts to offer some explanation and insight.

Finally, the *conclusion* (6) wraps up the thesis with a brief overview of the concepts discussed, the results of the work, and a direction for future work.

1.2 HRI and Motivation for Sociable Robots

There exists a rapidly growing consensus regarding the future ubiquity of robots. The number of consumer robots being sold is rapidly increasing, and the personal robots market has become one of the fastest growing in the robotics industry [1]. Research into countless areas of robotics and human-robot interaction is rapidly spreading throughout academia and industry. Companies and institutions alike are scrambling to establish standard research and development platforms[1]. Once established, these platforms will spur progress in this field by allowing new developments to be rapidly shared and applied by research groups around the world. The questions regarding what *form* these robots will take, what *purpose* they will serve, and how we will *interact* with them once they have entered into our lives, has not yet been sufficiently addressed.

1.2.1 Robots as Instruments

Robots already serve very important functions in our society, though not in the way in which yesterday's futurists would have predicted. The *Jetsons* and *iRobot* future is far from reality, and the immersion of robots into our world had taken a very pragmatic route. Up until a few years ago, the only sector of the robotics industry showing any real success was industrial robotics [1]. These machines, which tend to resemble huge mechanical arms, are a far cry from the robotic servant of our science fiction dreams, though the practical purpose they serve is undeniable. Most people go about their daily lives unaware of these robotic workers tirelessly enabling our modern lifestyle. The absence of robots from our daily life is rapidly changing.

In roughly the last decade, the robotics industry has seen rapid growth in areas outside of industrial robotics. As a result of this transition, robots are now beginning to resemble those of our science fiction inspired imaginings, in that they are designed to function in a human environment. Most notably, the *Roomba* vacuum cleaner is one of a few successful autonomous robots from the Massachusetts based company, *iRobot*. These robots serve a clear function, namely cleaning, as they autonomously scuttle

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[1] For example, Microsoft has created the Microsoft Robotics Studio, while the company Willow Garage, and the Personal Robots Group are attempting to establish their own robotics platforms

around our floors, gutters, and pools. The same company is one of many contributing to a rapidly growing military robotics industry spurred by the US government drive to increase the number of autonomous robotic troops. Already, autonomous vehicles survey the skies [69], explore above and below the ocean [43, 67], and of course roam the earth [25]. We are even seeing medical robots being employed to aid in many types of surgery [62, 68].

The robots mentioned above represent a major step beyond industrial robotics, where the applications involve roles directly embedded in a human environment. These robots do work in close proximity to people, but their function is not in any way human oriented. And although there is an interface between the robot and its operator, this is designed to be the most efficient and direct means of getting them to perform the limited function they were designed for. These robots act more like tools, than partners. They are directly controlled by a person, and may have varying degrees of autonomy, but their human interface is a means of accessing their function, rather than being a part of their function.

1.2.2 Robots as Social Partners

A new breed of robots is emerging. These robots are not only designed to operate in a human environment; rather, their function is fundamentally tied to human interaction. For these robots, their interface is not simply a way of getting them to do something, but is inextricably tied to their functional purpose. A robotic museum guide [18], is designed to show museum visitors around the exhibits, educating and providing guidance; however, without human interaction the robot's role would be meaningless.

The *Huggable* is a robotic teddy bear designed to bring comfort to hospital patients, as well as function as a tool for nurses to monitor patients and diagnose specific conditions [61]. *Autom*, a robotic weight loss coach, is designed to be placed on your kitchen counter or in your bedroom, and help motivate and guide you through a successful weight management program [38]. These are social robots in that their function fundamentally revolves around human interaction.

As robots roles become increasingly purposed for human interaction, and their operation increases in sophistication, it makes more and more sense to design them with a social intelligence. Humans are social animals, and we are very good at communicating with, learning from, and teaching each other. We are social to the extreme that we will readily treat objects and devices of sufficient complexity as if they were social entities [53]. Research clearly suggests that this propensity for social interaction should make us naturally adept at interacting with any entity whose behavior is human in nature. This will become very relevant as the roles and abilities of these machines become increasingly sophisticated.

Much of the technology we use has the unfortunate consequence of becoming more difficult to use as it increases in sophistication and complexity. With computers, for example, it can take novice users weeks or months before they are able to use even the most basic available features. Many of the more advanced, though potentially useful, features remain hidden to all but the most advanced and dedicated users. Personal robots, which would likely bypass most consumer technology in terms of complexity and capability, stand to suffer the same fate. A social interface may provide a solution to this problem in applications where the tasks and functions are geared toward human interaction. If people can use their naturally existing repertoire of language and nonverbal communication, then the learning curve becomes almost non-existent.

Humanoid robots are especially suited for this type of interaction. With the potential for expressive facial features, actuated limbs, and advanced mobility, they can employ much of the same paralinguistic vocabulary to which humans are naturally attuned. An array of sensing capabilities are in many ways analogous to human senses, allowing these robots to experience the world much like a person, with the added benefit of sensing modalities unique to robots. They cannot only work and navigate in a human environment, but they can also *perceive* human belief and intention using the same verbal and nonverbal cues that humans use when interacting with each other.

In order to effectively interact with these social machines, we will need to endow them with sophisticated social intelligence. Breazeal talks about the need for a genuine social intelligence, one that will not break down or deviate from human expectation during unconstrained interaction [13, 16]. To achieve a social intelligence of this sophistication, a deep model of human behavior would need to be embodied by the robot. It would need to conform to a vast array of human social behaviors, many of which we take for granted. One of these aspects of social interaction between people that would be vital to a socially intelligent robot is the ability to mutually change human belief and behavior between itself and its human interactant.

1.3 Persuasive Robotics

> The most common human enterprise is, by and large, influencing other people. Humans are involved in thousands of persuasion attempts each week, from the mundane acts of getting your roommate to turn down the stereo or persuading your partner to arrive on time, to more important issues such as getting your partner to marry you or persuading a troubled friend to seek counseling [58, p.165].

Persuasive Robotics is the study of persuasion as it applies to human-robot interaction where persuasion can be generally thought of as an attempt to change another's beliefs or behavior. The act of influencing others beliefs and behaviors is fundamental to nearly every type of social interaction [32, 58, 4, 23]. Any agent desiring to seamlessly operate in a social manner would need to incorporate this type of core human behavior. Within the framework of sociable robots, persuasive robotics presents a structure through which both human and robot belief and behavior can be mutually influenced.

1.3.1 What is Meant by Persuasion

There is no completely agreed upon definition of persuasion. Gass et al., while considering multiple views on the topic, write that "persuasion involves one or more persons who are engaged in the activity of creating, reinforcing, modifying, or extinguishing beliefs, attitudes, intentions, motivations, and/or behaviors within the constraints of a given communication context" [32]. It should be made clear that persuasion is a conscious, intentional act, which requires that the recipient be aware of the attempt, and have the ability to decline. This is in contrast to coercion, which is generally thought to involve force, or a lack of conscious choice.

Persuasion is a fundamental part of nearly every type of social exchange [32, 58, 4, 23]. An innocent phone call from a friend, inquiring about dinner plans for instance. The friend may ask *How about we go for pizza? I've been craving it all day.*, which might be met with *Oh, I had that for lunch, how about Chinese food instead?* This simple communication illustrates a subtle, yet clear, exchange in which both sides attempt to influence the other using clearly formulated arguments with the intent to change each other's behavior. Children are masters of persuasion, employing a wide range of both subtle and dramatic tactics in order to, for instance, convince their parents that a certain holiday present is absolutely necessary. The young child desiring the latest toy is a master of such tactics. A simple conversation with a friend regarding plans for the evening may involve many levels of influence including subtle changes in tone of voice, carefully worded arguments, and reliance on a store of experience gained from many similar past experiences. Education revolves around the process of actively changing people's beliefs. If educators were unable to effectively instill beliefs into their pupils, the entire educational system would crumble.

How persuasive an individual is, depends on a number of factors, but ultimately it revolves around how that individual is perceived. For example, someone seen as more credible, intelligent, or trustworthy, may be more successful in getting others to comply with a request. An understanding of how to alter these perceptions, getting someone to be perceived as more credible for instance, would lead to the ability to increase one's persuasiveness. The ability to alter how one is perceived is not only a means of increasing persuasiveness, but a way of increasing the effectiveness of any number of exchanges. For instance, even with identical lesson content, people would likely learn more, and have a more enjoyable learning experience from a teacher perceived as more intelligent, honest and friendly [32].

1.3.2 How Persuasion Applies to Human-Robot Interaction

For a sociable robot to be truly effective, it must be able to interact with people across many different social dimensions. Social psychology tells us that persuasion is a fundamental part of human social interaction. From short one-on-one exchanges, through fierce arguments, to the political arena – attempts to change belief and behavior are constantly all around us, with every interaction. How we perceive and respond to these requests are important defining factors of our character. Moreover, how we attempt to influence those around us, whether through subtle and/or explicit methods of communication, is a complex social dance involving everything from nuanced paralinguistic expressions to carefully crafted arguments. Persuasion is not an art reserved for the ambitious car salesman – far from it. Attempts to change our own and others' belief systems and behavior are all around us with everything we do, and a truly social robot would have to incorporate this type of behavior into its core social intelligence.

Within the framework of social robots, persuasive robotics provides a structure within which human and robot belief and behavior can be mutually influenced. This ability to alter belief and behavior is fundamental to human-human interaction, and thus must be incorporated into any fundamentally social human-robot interaction. Just as human persuasion is bi-directional, humans and robots would need to be able to influence each other.

Human Influence of Robots

Incorporating social competence of persuasion and influence into robotic social intelligence, would create a framework within which robots might learn from people and build their model of the world. The study of persuasion gives us an understanding of how and why people come to believe the things they do. Humans have developed a wide array of rules which they apply in order to simplify the process of filtering out valid and useful information from potentially deceitful and harmful information. These rules also help us make decisions when we are presented with multiple sources of potentially conflicting information. These abilities would need to be employed by any robot designed to be a fluent social actor. How people would communicate with, and teach robots is a widely addressed research area, one which this thesis does not attempt to cover. However, we do suggest that persuasion could be considered as a possible framework for designing a social robot's mechanisms for evaluating, creating, altering, and extinguishing beliefs and behaviors.

Robots Influence of Humans

This thesis focuses on the way in which robots influence people. This process might be as simple as that of a robot attempting to convey some piece of information to a human counterpart. How this information is received would depend on how the robot is perceived. A museum tour guide, for instance, would be quite ineffective if all of the information it presented was met with skepticism and doubt. If the robot's appearance or behavior could be altered in some way as to increase its persuasiveness, it would be much more effective at conveying information. The research in this thesis examines exactly this: How do changes in a robot's appearance and behavior alter its persuasiveness and how it may be perceived?

A robot, designed to be an effective persuader, may prove to be important for many reasons and in any number of situations or practical applications. From robots in health care, to education, the need to effectively alter human beliefs and disseminate believable information is vital. There are many reasons beyond the practical ones which motivate the exploration into persuasive robotics. Ethical considerations drive us to fight the possibility of robot's manipulating or influencing humans in unexpected or negative ways with the knowledge of how exactly humans are influenced by machines. And of course, a number of research areas stand to be elucidated, as knowledge of how humans perceive and respond to robots can teach us much about human psychology, amongst other things. The following section explores the motivations behind the study of persuasive robotics.

1.3.3 Why Persuasive Robotics?

Practical

Any application requiring that a robot be a source of information, or otherwise trusted, is an obvious candidate for a conscious effort to increase the robot's persuasiveness. It's easy to imagine a hospital robot delivering food and medicine to patients. Crucial to the success of the robot in this role would be the way it is perceived. If seen as intimidating or unintelligent patients may become uncomfortable or suspicious that the medicine or information provided was incorrect. The ability to design the appearance and behavior of this robot, such as to maximize the patients comfort, would be highly desirable. For instance, a subtle change, such as the distance at which the robot stands from the patient, may make a significant difference in the patient's degree of comfort.

A robotic weight loss coach would need to change people's diet and exercise habits and provide them with believable information regarding health and nutrition [38]. Beyond weight loss, it is easy to imagine robots acting as partners in efforts to change any number of undesirable or unhealthy behaviors such as smoking, abuse, drug use , etc. A robotic receptionist, educator, or tour guide, would be useless if the information it provided was met with skepticism or disbelief. Any robot whose role involves disseminating information or education would be limited in effectiveness with the believability of the information it provides.

Search and rescue operations might employ robots as first responders before humans are able to arrive on the scene. These mechanical rescue workers would need to provide the injured survivors with potentially life saving information, not to mention immediate emotional and bodily relief. Robots might even be used as mediators in hostile situations, perhaps even sent into battle zones or hostage situations as a method of establishing some sort of resolution. Although in this type of scenario the robot might be controlled to some degree by a human operator, this research might inform the robot's appearance and what mannerisms might be appropriate for the robot's operator. in an emergency evacuation it would be important for the robot to be seen as trustworthy and friendly in order for civilians to comply with its request.

Persuasion might actually be used as a tool for increased robot autonomy or survival in real world applications. A video circulating around the internet shows *Pleo*, a toy dinosaur robot with some learning and interactive capabilities, being choked, thrown, and otherwise abused. The goal of the assailants is actually innocent; they are testing the toy's ability to stand up to the abuse it might undergo in a typical household. Watching the video though, gives the distinct and unnerving impression that a conscious feeling entity is being mercilessly abused. This sympathetic or even disgusted human response is obviously not logically appropriate (the robot has no real feelings) and would surely not be afforded to a toaster under similar testing conditions.

It is in the lifelike appearance and behavior of *Pleo* which triggers a set of automatic responses. When held tight, the dinosaur squirms and wiggles uncomfortably, and holding its neck results in a distinct choking sound. Though a toy designer might consider these features that add to the realism of a toy, they might serve a much more important function. It would not be difficult to imagine *Pleo*, narrowly escaping certain death at the hands of a "curious" child, who was persuaded to loosen his grip by a wriggling and choking toy. Though this is not a sure means of salvation, it

Figure 1-1: Pleo, an interactive robotic toy dinosaur being stress tested.

may very well save a few robots, and benefit the company producing the toy in the process.

This method of leveraging our natural social responses to obtain sympathy or help, may prove to be a useful tool for autonomous robots of the future. As robotics matures, the leash between human operator and robot lengthens, both figuratively and literally. Autonomous robots performing urban tasks may need to travel relatively large distances, between buildings on a school campus for instance. During this task, they may run into a technical problem, such as getting lost or stuck, which any layperson may be able to assist with. The ability to solicit bystanders for help may be in increasing operation time of highly autonomous robots.

The degree to which a human complies with a robot's request, can be used as a tool for measuring how that robot is perceived. A robot that is more persuasive is likely to be viewed more positively along a number of different social dimensions including intelligence, friendliness, competence, and trustworthiness[2]. These attributes

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[2] Though compliance to a request does not guarantee more positive views along all of these dimensions, these are commonly associated with persuasiveness.

are vital for a natural, comfortable and productive interaction in any imaginable application. Whether a robotic weight loss coach, museum guide or hospital assistant, the principles guiding persuasion can also be applied to improving the effectiveness of these robots.

Ethical

Understanding how a robot is able to change human belief and behavior helps us to develop ethical guidelines in terms of how HRI should be structured. It is easy to imagine a scenario where a robot gains an emotional stronghold over a human, not maliciously, but rather as a consequence of people's propensity to treat objects as conscious social entities [53, 64]. Widely read books, such as *Love and Sex with Robots* [42], are predicting a future where intimate relationships between humans and robots are commonplace. A number of countries are taking measures to draft ethical guidelines for the design of robots and how they might be integrated into our society [65], and major scientific publications are addressing the issue [56].

Ultimately it is up to the designers and manufacturers of these machines to consider the behaviors that they incorporate into their social intelligence. Concrete knowledge of how humans perceive and respond to robots would allow them to be designed to avoid any undesired or unexpected manipulative or harmful behaviors.

Research

There is much to learn from observing how people treat and respond to robots under different circumstances. The process of developing a social robot may teach us as much about engineering and algorithms, as it may potentially teach us about human psychology. It might even be possible to construct highly controlled experiments between humans and robots that would be impossible to test between humans and humans. Robot behavior is, by nature, easily repeated or held constant over many trials and varying external conditions. Humans on the other hand, despite their best efforts, exhibit a wide array of subtle verbal and nonverbal responses to changes in their environment.

1.4 Summary

This thesis attempts to define and explore the notion of *persuasion* in robotics through the selective application of methods and concepts from the disciplines of social psychology as they relate to social influence. A brief overview was presented that defines the unique properties and characteristics of robots acting as social partners, particularly in the context of HRI and within the mainstream conception of robots as automated machines. We have attempted to define what is meant by persuasion and how such notion may be applied to human-robot interactions. Finally, we suggest and coin the term *persuasive robotics* to include the body or research relating social influence to HRI.

In the following chapter we provide for some background definitions that support and review the methods by which to identify, evaluate and control human persuasion. In the context of human persuasion, as it is defined in the social sciences, we discuss measures such as gender, credibility and nonverbal behavior. With regards to persuasion as it may be applied to machines we present some related work in persuasive technology and reconsider the measures and their implications as they have been discussed in the context of human persuasion.

The thesis as a whole combines empirical research conducted through studies and experiments along side theoretical speculations supporting the methodological integration of social influence and robotics.

Chapter 2

Background

Social Psychology presents us with an extensive tradition of research into persuasion and social influence. Much of this knowledge has significant theoretical and practical relevance to the maturing field of human-robot interaction (HRI). This is specifically the case when applying theories and concepts from social psychology to sociable robotics.

This relatively new field has only recently begun to gain momentum, and only in the last decade or so with the work of Breazeal and Kismet [16], have the fields of HRI and social psychology really begun to merge. There now exists a rapidly growing body of research into how we might design robots as partners, along with methods of and for evaluating such interaction [30, 16]. The topic of this thesis - *Persuasive Robotics* - as defined in the introductory section (1), builds upon this disciplinary fusion and, as such, it is located in a relatively unexplored area of a new research field.

Persuasion, as it applies to HRI, has received almost no research attention, and in those cases in which it is addressed, it is typically mentioned only as a small portion of a larger research focus. The field of human-computer interaction (HCI) and embodied virtual agents has devoted more attention to this topic than the field of HRI. Computers and mobile technology are now becoming popular platforms for exploring attitude and behavior change [28]. And the persuasive abilities of virtual humans is being explored from a number of different angles [7, 34, 6, 19, 20].

The following section will begin with a very brief overview of the relevant areas of social psychology and the study of persuasion and social influence. That will be followed by a survey of existing research into persuasion and HRI, as well as some of the most relevant research into persuasion and HCI.

The chapter is structured so that issues and topics in persuasion are reviewed both in human-human interaction and in human-machine interaction. Such structures afford and promote comparisons between the respective fields of social psychology and HRI. The topics covered include gender differences, credibility, and nonverbal behavior. In addition, we provide an overview of state-of-the-art work in persuasive technology building upon and referring to the same topics and issues. Finally, relevant definitions from the field of sociable robotics are presented and discussed.

2.1 Persuasion and Humans

A cohesive, agreed upon definition of persuasion is difficult to come across. Gass et al., in their consideration of multiple disciplinary views, propose that "persuasion involves one or more persons who are engaged in the activity of creating, reinforcing, modifying, or extinguishing beliefs, attitudes, intentions, motivations, and/or behaviors within the constraints of a given communication context" [32]. In this light, it should be made clear that persuasion is, in fact, a conscious, intentional act, which requires that the recipient be aware of the attempt, and have the ability to decline. This is in contrast to *coercion*, which is generally thought to involve force, or a lack of conscious choice.

How persuasive a person is depends on many factors, and is considered by many disciplines to be an active research topic. Certain elements of how an individual is perceived, such as credibility, trustworthiness, or intelligence, are considered to be powerful determinants of persuasiveness. This perception is dependent on a wide array of qualities such as attractiveness, voice quality, and/or fame. Physical behavior, such as touch, eye contact, mimicry of body movements, or invasion of personal space, can count for major components of influence. In some cases persuasive attempts may rely on our subconscious responses to certain behaviors, such as the desire to reciprocate gifts and favors, or submit to a request if it is preceded by a larger one first [23, 32, 4].

2.1.1 Gender

In an overview of the current literature on gender and persuasion, Carli finds that men, due to prevalent gender stereotypes, tend to be more persuasive than women [58]. The explanation offered to support such claim, is that women, more than men, are required to establish themselves as competent and likable sources in order to be influential. Research clearly shows that competent and likable sources are more successful at exerting their influence [22, 58]. In this, men have a distinct albeit unfair advantage. Research has shown that the perception of men's competence is, in many cases, unrelated to the quality of their performance. In cases where the performance of men and women are manipulated to be identical men retain the influential advantage [32, 58].

However, there is a much higher, gender stereotype driven, expectation for women to behave in a communal, warm and likable manner. Likeability is more strongly associated with social influence for women than it is for men [22]. There is also evidence that men particularly expect this type of communal behavior. Gass et al. make the important observation that it is not any inherent quality of the genders that effect their persuasive power, but rather a difference in people's goals, plans, resources, and beliefs [32].

These gender differences may be important in thinking about how gender should be assigned to social robots in various environments and domains. Many of the most immediate likely applications such as healthcare, eldercare or behavior change - such as weight management - call for a robot that should be perceived as a warm, caring and communal agent. In these cases a female robot may be the most appropriate gender choice. For roles that require a more dominant or assertive personality, a male robot might be most effective.

Ward et al. discuss cross-sex context as a factor in the persuasibility of men and women [66]. They give evidence and some explanation for an observed cross-sex persuasion effect where people tend to be more persuaded by communicators of the opposite sex. This is presented to contrast a previously prevalent view, that women tended to be more easily persuaded than men. The paper argues that because many early studies used a male communicator, the data would erroneously show that women were more persuadable than man. One explanation offered points to role-related expectancies derived from status inequalities found in the larger society. Women tend to follow a role of deference to male authority, while men conform to a norm of chivalry.

2.1.2 Credibility

Simply put, credibility can be defined as believability [29]. The information that a credible source provides is more likely to be believed by a receiver. Because this information is more likely to be believed, it is also more likely to be internalized, and incorporated into the receiver's beliefs. Thus, a credible source is more persuasive, in that their influence attempts are more likely to result in attitude change [32, 58, 29, 23].

Credibility is a multidimensional quality made up of a number of different factors. Though there is not complete agreement regarding ways in which to qualify and quantify credibility, consensus seems to rest on there being three primary dimensions (expertise, trustworthiness, and goodwill), as well as at least three secondary dimensions (extroversion, composure, and sociability). Expertise refers to how competent or informed a communicator appears. Celebrity spokespeople are good examples of the fact that the expertise doesn't necessarily have to be in the topic of communication [54]. Trustworthiness is related to how ethical, fair, or honest an individual appears to be. A source may seem an expert, but not at all trustworthy (consider a knowledgeable but deceptive used car salesman). The third primary dimension, goodwill, is described as being synonymous with perceived caring [44].

Credibility is also considered to be a receiver-based construct, in that it is based entirely on how the source is perceived, rather than any inherent quality. This is important to understanding how credibility is created, and how it can change. Not only can the same individual *receive* completely different credibility ratings from two different people, but those ratings can easily change based on any number of factors. This is very apparent in the political arena where a single piece of leaked information can be detrimental to an entire political career [32].

2.1.3 Nonverbal Behavior

Andersen, a well known persuasion scholar, writes that "nonverbal communication is as important as, perhaps more important than, verbal communication in persuading others to change their attitudes and behavior" [3, p.273]. Among these forms of nonverbal behavior are those that are referred to as nonverbal immediacy behaviors. These behaviors, such as eye contact, touch and close distances, can act to significantly enhance the persuasive effect of a message or request [57, 3]. This is especially true in cases where the communicator is liked by the receiver of the message.

Touch is shown to consistently increase compliance, even in interactions between strangers. In a well known study, waitresses received significantly more tips if they touched the customer's arm after delivering the check [24]. A separate experiment showed that people were more likely to return change left in an airport phone booth if they received a light touch before the request [39]. A meta analysis of a number of studies involving touch showed that this behavior was consistently effective in increasing compliance to a request [57].

Expectations Violations Theory, which is an alternative theory explaining the persuasive effect of immediacy behaviors, suggests that when one's personal or cultural norms are violated the persuasive impact of immediate behaviors may be reduced [21, 58]. For example, there may be a very different response to being approached by a young, well groomed, attractive individual, and by a disheveled threatening character. This highlights the importance of ensuring that robots are likable, and that the human with whom they are interacting with is comfortable with them.

2.2 Persuasion and Machines

Nass and Reeves, in their seminal book, *The Media Equation*, expose an unintuitive and totally unconscious propensity for people to treat their computers in the same way they treat other people [53]. They illustrate that even relatively simple devices, such as televisions or computers, running basic computer programs elicit the same type of psychological response that another human would. This precedent work truly established the inherent psychological link between humans and new media, forming an important part of the foundation of this research.

Though Reaves and Nass hypothesize that their findings are applicable to all forms of new media, they do not address how this social connection might change with increasingly realistic and socially capable embodied technology. It is believed that these effects will be stronger as the nature of the media becomes more capable of natural social expression and interaction. A recent study has even found biological evidence to support the claim that as a type of interactive media increases in human likeness, the brain increases in its tendency to build a model for that media's mind [40]. In other words, there is biological evidence to suggest that as something becomes more human-like, our fundamental treatment and understanding of it becomes more human-like.

Virtual embodied agents have been found to push this human computer relationship even further. It has been shown that integrating a human like form into a softwares interface improves people's perception of that computer in ways known to contribute to persuasiveness [51, 71, 47].

A number of studies have been performed which successfully apply many of the persuasive behaviors being examined in this work to virtual embodied agents [7, 34, 6, 19, 20]. This is of the utmost relevance to this work; if people respond to human-like social cues given by on-screen characters, then it seems very likely that the same, or stronger reaction will be elicited by a humanoid robot.

A handful of studies have compared virtual to physical embodied agents in ways relevant to persuasion [41, 60, 52, 50, 49]. Though the results are mixed, they do suggest that people respond more favorably to a robot in ways known to contribute to persuasiveness such as credibility, likeability, social presence, and intelligence. Of these studies, only a few have actually looked directly at persuasiveness, and while the data does suggest that robots have an advantage over their physical counterparts, the work is sparse and to some degree inconsistent [59, 37, 33, 49, 8]. A characteristic of these studies, differentiating them from this work, is the robots they use, which are non-mobile, minimally expressive, and lack the ability to physically interact with their environment. This work hypothesizes that a robot with a greater ability to physically express itself and interact socially with its environment will be rated higher in many ways, including persuasiveness.

Most similar to this proposal, is Cory Kidd's PhD work, which looks at how a social robot can help people to lose weight over a long-term interaction [38]. His work is informed by methods used in health care, rather than persuasion and social influence. And he is looking at long-term interaction with a stationary robot with little ability to show emotion physically, whereas this work will examine a mobile robot with an expressive face, during short-term interactions.

2.2.1 Persuasive Technology

A new field called Captology, created by B.J. Fogg at Stanford, explores how computers, as a persuasive technology, provide a key advantage over traditional forms of media, namely interactivity. Fogg lists a number of ways in which computers may even have an advantage over humans, such as persistence, anonymity, and the ability to handle huge volumes of data [28]. Captology, as Fogg has defined it, has only a small social emphasis, and has yet to be applied to robotics.

2.2.2 Gender

In [49] Powers et al. report on an experiment in which they explored how robot gender changed the way that information is elicited from subjects. In this experiment, they hypothesized that by changing the persona or gender of the robot, they would change the perceived common ground that the subject has with that robot. Specifically, they hypothesized that a female robot would be more knowledgeable regarding dating practices than a male robot. Interestingly, their findings actually pointed to a gender preference, where men tended to report the male robot as having more dating knowledge, while women reported the female robot as being more knowledgeable. Also, subjects tended to say more words overall to the male subject (about the topic of dating), though men said more words to the female robot, and women said more words to the male robot. This finding shows that the appearance or perceived persona (in this case gender) of a robot can alter how people perceive and respond to it. More specifically, it suggests that attributes such as gender should be matched to the role. An earlier study also confirms that the matching between role and appearance/behavior is important [33].

A study [52] aimed at comparing a robotic rabbit to an onscreen equivalent also measured differences in how male and female subjects perceived the robot. The subjects were presented with one of three different scenarios (retail sales, nutrition and diet, reading survey) and then reported their experience in a questionnaire following the interaction. A notable gender effect was that women tended to find the robot to be more credible, while men remembered more from the interaction.

Cory Kidd in [37] used the desert survival task to measure persuasiveness. In this task, subjects interacted with a male gendered robot whose eyes and neck were able to move. The robot and the subject planned what supplies they would bring in order to survive an extreme situation. By measuring the subject's willingness to comply with the robot's suggestions, its persuasiveness can be determined. It was found that women were significantly more likely to comply with the robot than the male subjects.

In [34], Guadagno et al. subjects listened to a persuasive communication on a proposed change in university policy presented by a gendered on-screen virtual agent. Their before and after opinion on the topic was compared, in order to ascertain the degree to which their beliefs were influenced. It was found that there was a same sex preference, in that the subjects were more likely to change their attitude when the persuasive communication was presented by an agent of the same gender. Interestingly, this same gender preference actually reversed when the behavioral realism of the virtual human was low. Though this study did not use a physically present robot, it is believed that the precedent set by studies of virtual agents and persuasion is highly relevant to understanding persuasion in HRI.

A number of studies using synthetic speech and a computer have shown that the effect of prevalent gender stereotypes (discussed in 2.1.1) holds true for human computer interaction [53, 45, 46].

2.2.3 Credibility

As in human-human interaction, credibility is an important precursor to persuasion. A source seen as more credible would more likely be complied with, and the information it presents would be more believable. It is expected that virtual or robotic characters would conform to similar rules regarding perceived credibility as their human counterparts [19].

Though not much work has been done in the area of robotic credibility, Fogg et al. present a very informative paper on the topic of computer credibility [29] which should be very relevant to robotics research. Fogg et al. propose a number of situations in which computer credibility matters. Those relevant to robotics are listed below:

- act as knowledge sources
- instruct or tutor users
- act as decision aids
- report measurements
- report on work performed
- report about their own state

It is clear from this list that the motivations behind understanding and increasing computer credibility are equally relevant to robotics applications. Drawing from research into human-human interactions, Fogg et al. describe factors effecting computer credibility. A computer perceived as being a member of a person's "in group" would be perceived as more credible. Also, because people tend to perceive those similar to them as more credible, a more similar computer would also have the same effect.

In the study by Reaves et al., mentioned above there was a significant credibility effect caused by the presence of the robot. The on-screen robot was found to be more credible, but only for women. Men showed little difference in reported credibility between the on-screen and physically-present robot.

Kidd designed an experiment which compared the subject's response to a humanoid robot in two separate tasks; a teaching task and the desert survival problem. Subjects found that the robot was significantly more credible in the teaching task [37, 36].

2.2.4 Nonverbal Behavior

Breazeal, in the design of Kismet's behavior, as well as in the definition of what traits matter for sociable robots, put significant emphasis on paralinguistic forms of communication such as gaze, facial expression (display of emotion), and head pose [16, 15, 11, 13]. These nonverbal forms of communication were paramount to the success of Kismet as a social actor, and a continuing focus throughout the later work of Breazeal, including Leonardo [12, 63, 14] and the Huggable [61]. This work focuses more on the general aim of *social fluency* in unstructured social interaction, rather than the specific goal of changing belief or behavior.

A study by Goetz et al. [33] points to the importance of matching robot appearance and behavior to task. In this study the robot's appearance is changed from more human like to more machine-like, the age is changed from youthful to adult and the gender of the robot is changed from male to female. The effect of the robot's appearance and behavior were validated by measuring the subject's compliance to a request to perform a physical activity. They found that people complied more with a robot whose demeanor matched the seriousness of the assigned task.

The effect of interpersonal distance using embodied virtual agents has been explored to some degree, [5, 6, 20] though this topic has not been widely addressed in human robot interaction. Generally speaking, people tend to afford more distance to virtual humans as their presumed agency (the degree to which they are controlled by a human) and their behavioral realism (the degree to which their appearance and movements are natural) increases. Other aspects of nonverbal behavior related to persuasion have also been explored using virtual agents such as touch and mimicry [7, 6].

The topic of proxemics or interpersonal distance between human and robot has been explored, though not in the context of persuasion [26, 2, 17]. In [26], Dautenhahn et al. looks specifically at how subjects prefer being approached by a robot in a home setting. Much of the research relating to proxemics in areas of both virtual and robotic agents has primarily focused on the distance subjects will naturally move to under different circumstances, given free range of motion. The focus of this research looks more at an imposed or controlled change in interpersonal distance, and what effect that has on persuasion.

2.3 Sociable Robotics

Kismet, created by Cynthia Breazeal, defined the field of Sociable Robotics, where sociable robots are expressly designed to interact and cooperate with humans using our natural communication modalities such as facial expression, body posture, gesture, gaze direction, and voice [16]. Ultimately, a social interface is potentially achieved, in which people are able to use their natural ability to communicate and learn as the primary mode of interaction. It is this model of socially aware HRI that Breazeal believes is an ideal form of interaction between humans and, eventually, their personal robots.

A robot capable of fluidly and autonomously interacting socially in an unstructured environment is not yet a reality, but there exists a large range of robots which may potentially be classified as social. Breazeal breaks down these robots into four categories of increasing social fluency [13].

- *Socially evocative* robots are more suggestive of a social or interactive ability, though this is only a superficial quality. Anthropomorphic children's toys would likely be useful examples of this category.

- *Socially communicative* robots use human-like social cues and communications modalities in order to facilitate interactions with people.

- *Socially responsive* robots combine the outward behavior of a socially communicative robot, with an internal model that benefits from interactions with people.

- *Sociable robots* are socially participative "creatures" with their own internal goals and motivations. This is the ultimate goal for social human robot interaction.

The area of social robots has expanded and now includes researchers at a number of institutions exploring various aspects of this field. For a comprehensive overview of research in this field see [30].

2.4 Summary

This chapter presented us with an overview of the relevant background material in both human-human interaction (social psychology), and human-machine interaction (HCI & HRI). We learned that there is a rich body of existing research in the area of social psychology regarding persuasion and influence. Because humans tend to treat interactive media in their environment as social actors, it is reasonable to use this as a starting point for understanding social HRI. There are reasons to believe that as the interactive media becomes more human-like (i.e. the transition from on-screen to physically present), the application of human social behavior will become more relevant.

Researchers in the fields of HCI and HRI are just beginning to understand the role of influence in interactive technologies. This is becoming a popular topic with the field of persuasive technology and associated conferences emerging, though this tends to be less socially oriented then the focus of this work. Researchers utilizing virtual humans in various types of virtual environments have explored a number of these topics, and this work will prove to be very important to extending the field to include physically present robots. Very few studies have explored the role of persuasion in HRI, especially in the way that this work intends to. What we have seen is that social factors do matter, social norms regarding gender tend to remain intact, and context is important.

Chapter 3

Experiment Overview

This section describes an experiment designed to test and evaluate the effect of certain aspects of a humanoid robot's appearance and behavior on its persuasiveness. The experiment, which took place in the Museum of Science in Boston (MOS) at Cahners ComputerPlace (CCP), consisted of a five minute interaction between subjects and the robot, during which the robot made a verbal persuasive appeal, requesting a donation to support technology distribution (see Appendix A). The amount of money donated was assumed as a measure of the visitor's compliance, and in itself provided a measure of the robot's persuasiveness. Following the interaction, subjects were asked to fill out a questionnaire which contained a number of additional subjective measures.

Various aspects of the robot's appearance and behavior were varied, in order to test what effect these had on the robot's ability to solicit donations. The gender of the robot was set to be either male or female, and was accomplished by changing the voice of an already androgynous looking robot. The robot's perceived autonomy was changed such that subjects were led to believe that the robot was either autonomous, or completely controlled by a human operator. In some cases, the robot would make an attempt to shake the subject's hand after the interaction, before the donation request. And finally, the interpersonal distance between human and robot was changed by moving the subject's designated standing position. These measures, as well as a detailed description of the study setup are discussed below.

3.1 Relevant Measures

3.1.1 Robot Gender

A potentially critical design decision for sociable robots may potentially be the choice of gender. As discussed in Section 2.1.1 we know that human gender matters, especially when it comes to assertive or dominant roles vs. communal roles. However, the role of robot gender has not been seriously considered and addressed in the context of human robot interaction, especially with respect to persuasion. If robot gender *does* play an important role in how the robot is perceived, it may inform future design decisions. Also, because some robots may be able to alter subtle attributes that signal gender (ex. voice), it might be possible to switch between male and female depending on the situation.

In other words, certain strategic decisions can be made with regard to gender selection and set-up which may be modified in relatively short periods of time depending on the context and/or the subject's anticipated response.

In this experiment we take advantage of an already existing robotic platform designed to look and behave androgynously. In this respect, only a change in voice is required to alter the perceived gender to an extent where such an alteration is noticeable and registered by the subject. No additional aspects relating to the robot's appearance were modified. Following this, the main assumption made within this context was that vocal properties were considered to be direct and discrete gender signifiers. A more detailed description of the gender condition can be found in Section 4.1

3.1.2 Perceived Autonomy

The perceived autonomy measure looks at how people's response to the robot changes when their *belief* concerning the *autonomy* of the robot is manipulated. In this condition, some subjects were explicitly told that the robot was controlled by a human operator, and that operator was made visible during the interaction by lifting a normally lowered curtain (see Figure 3-1). This is in contrast to what was intended to be a general assumption that the robot was autonomous, and artificially intelligent to some degree. Though this was a *Wizard of Oz* style study (the robot's words and actions were completely predetermined), special care was taken to ensure that the subjects were not aware of this fact. Details of this condition are reviewed in the following results section: 4.2.

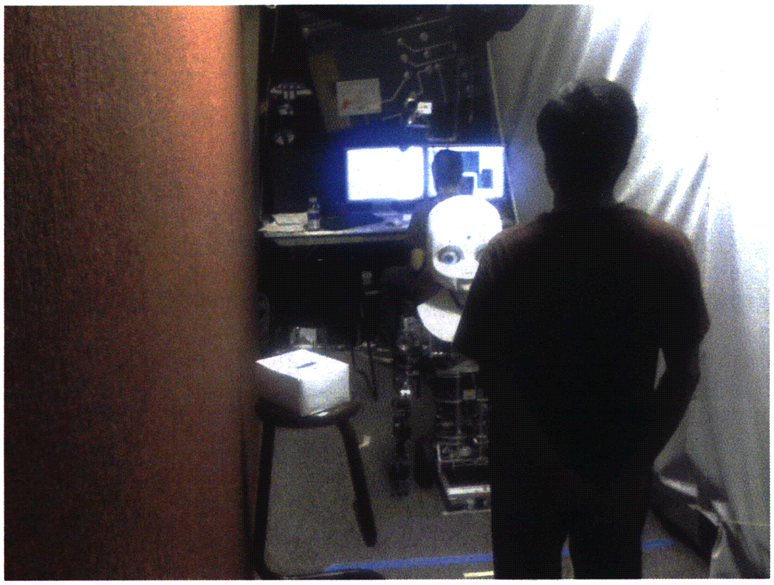

Figure 3-1: View showing the subject's perspective during the perceived autonomy condition. The robot operator is clearly visible behind the robot.

3.1.3 Touch

Touch, as discussed in Section 2.1.3, is among a group of behaviors known as *nonverbal immediacy behaviors.* Under the right conditions, defined here as conditions that provide for a comfortable environment in which to communicate, they can signal warmth, and a desire to interact. The result is that the recipient of the touch would feel more comfortable, and the psychological or physical distance between both communicators would be decreased. This type of behavior is known to increase the source's persuasiveness. If the source of the touch is considered threatening, or dangerous, than the gesture may have no effect, or even the opposite effect.

In this experiment the robot instigates a handshake towards the end of the interaction. The robot operator, watching through a video camera (see Figure 3-4), initiates the *shaking* and *retract* procedure in coordination with the subject's reciprocation of the robot's gesture. The whole process takes approximately five to ten seconds. See Section 4.3 for a more detailed description of this condition.

3.1.4 Interpersonal Distance

Like the sense of touch, interpersonal distance is also included within the group of nonverbal immediacy behaviors. As discussed in Section 2.1.3, decreasing interpersonal distance may increase persuasiveness if the communicator is considered rewarding, though it may have no effect, or even a negative effect, if the communicator is unattractive or unrewarding. *Proxemics*, which is the study of the distances between people as they interact [35], will necessarily come into play during interactions between humans and mobile robots. This is especially true when the robot approaches strangers, such as in a museum or hospital environment. It will be important to determine the optimum way in which the robot approaches, in order to maximize the service that the robot is able to perform.

In this study, interpersonal communication is controlled by designating the standing position of the subject. In the *close* distance condition the subject stood at approximately 2.5 feet from the robot, whereas in the *normal* distance condition the subject was asked to stand at 5 feet. See Section 4.4 for a more detailed discussion of this condition.

3.2 Method

The study was conducted in two phases, a *non-interactive* phase, and a second *interactive* phase. This separation was not premeditated, and came out of a perceived need based on feedback from participants and observed interactions. It seemed that the behavior of the robot in the first phase was violating participants' expectations, causing confusion or even frustration, resulting in a less positive experience. There was an effort made in the design of the study to satisfy the aims of the Museum of Science, and, specifically, Cahners ComputerPlace. These aims, though primarily educational, also demanded a comfortable and enjoyable educational experience.

In the first phase of the study the robot was not interactive; it performed a predetermined set of movements and utterances with no feedback from the subject. In the second phase of the study, simple interaction was added. This interaction included a number of general questions such as "What is your name?", or "How much do you know about robots?" whose response would be identical for all answers. It was assumed that this would alter people's perception of the robot, and create a more rewarding experience. Though subjective observation of the interactions and informal post-study interviews *did* seem to reveal that the change had a desired effect, strangely there was little change in the general response of subjects as measured by the dependent variables. Participants' donation behavior, as well as their questionnaire responses seemed to be unaffected by the added interaction. Due to this, many conditions from the two study phases were combined, when appropriate, to attain greater statistical power. Formal justification for this can be found in Chapter 4, in the sections where this combination occurred.

3.2.1 Participants

Participants included 340 museum visitors to Cahners ComputerPlace in the Museum of Science (142 female, 194 male, 4 unknown)[1]. All participants had entered the CCP freely and willingly, unaware of the study being run. Only adults over the age of 18 were able to act as study subjects, though minors were able to accompany adult subjects. Also, because the post-study questionnaire required English fluency, some prospective subjects were asked not to participate in the study[2]. All participants were given $5 for participation, though many donated some or all of their money.

A number of questions were asked of the subjects following the study, which gives some insight into the demographics of the populations. 75.3% ($n = 256$) of the participants were Caucasian, 5.9% ($n = 20$) were Asian, 5.9% ($n = 20$) were Hispanic, 4.4% ($n = 15$) were Other, 2.4% ($n = 8$) were African American, 0.3% ($n = 1$) was Pacific Islander, and 5.9% (n = 20) were unknown. Subjects reported their level of education to be 30.9% ($n = 105$) graduate school degree, 27.9% ($n = 95$) college degree, 18.5% ($n = 63$) some college, 9.1% ($n = 31$) some graduate school, 6.5% ($n = 22$) high school degree, 1.2% ($n = 4$) some high school, and 5.9% ($n = 20$) unknown. Age ranged from 18 to 78 ($M = 38.11, \sigma = 13.361$).

Using a seven point scale, participants were also asked to self report their knowledge of computers ($M = 4.59, \sigma = 1.575$), artificial intelligence ($M = 2.67, \sigma = 1.437$) and robotics ($M = 2.79, \sigma = 1.51$). When asked if they had heard of the MDS robot before the study, 11.2% ($n = 38$) responded that they had, 81.8% ($n = 278$), responded that they had not, and 7.1% ($n = 24$) are unknown.

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[1] Unknown values represent subjects who did not complete the questionnaire but did participate in the study, and were counted for the donation measure

[2] Any visitor that so desired, would be allow to interact with the robot, though in some cases the data was not used for the study

3.2.2 Setup

Museum of Science: Cahners ComputerPlace

The study took place in Cahners ComputerPlace (CCP) in the Museum of Science (MOS) in Boston (see Figures 3-2, 3-3 and 3-4). CCP is an exhibit at the MOS devoted to hands on technology education with a special focus on computers and robotics. Dan Noren, the program director, has a long history of academic partnerships, and at the time of this study at least two other active experiments involving robotics and virtual relational agents were being run. The space itself contains over a dozen computers running educational software open to public use as well as a number of robotics exhibits.

Figure 3-2: Cahners ComputerPlace area. The upper left image shows the robot operator entrance to the study space covered by a gray curtain. The lower right image shows the subject entrance to the study space covered by a gray curtain.

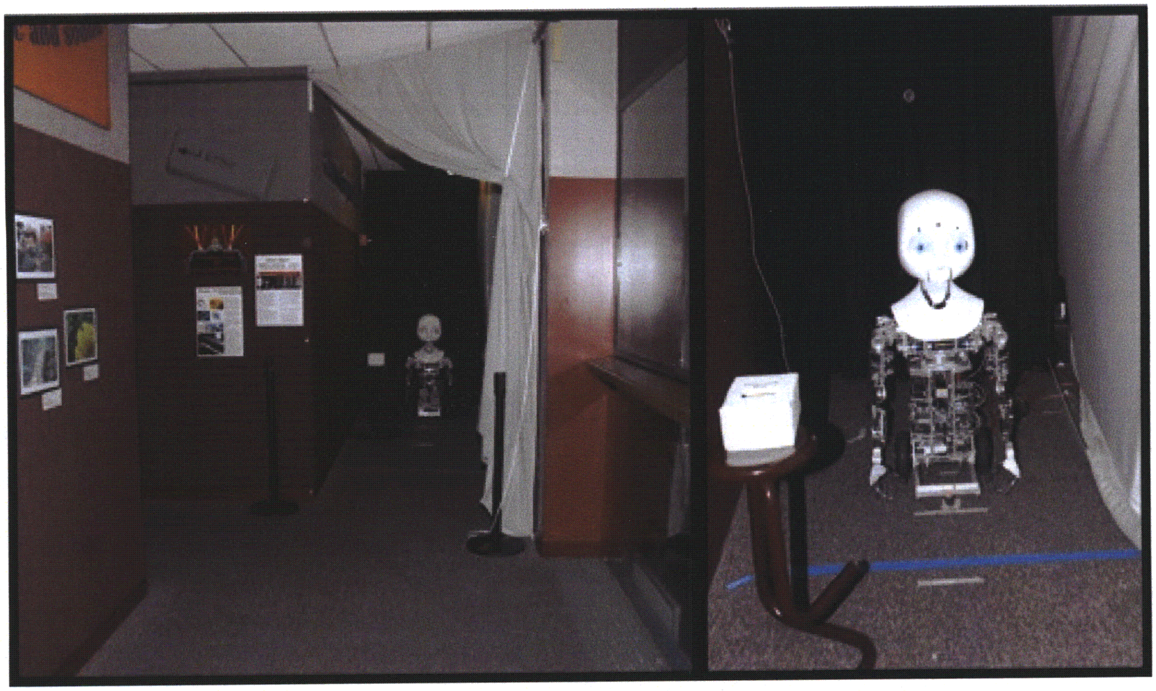

Figure 3-3: Area in which the study was conducted. Left image shows a wider perspective. Right image shows a closer view in which the donation box can be seen on the left side.

A space within CCP measuring approximately 8' by 20' was devoted to this experiment. The space was originally designed as a low traffic side hallway, with the longest sides being walls. The two shorter sides were curtained off, creating a completely enclosed space. One end was used as an entrance and exit, with the other end leading to a small robot operator area (see Figure 3-5). This area, which was also curtained off from the rest of the exhibit space, was the control center for the study, containing all the computer systems used to control the robot.

There were two posters used to advertise the presence of the MDS robot in CCP, though there were no specifics about the study on the poster. One of these posters was positioned near the entrance of the CCP space, and the second poster was located in a central area of the museum, near the escalators. These were the only forms of advertising done. All other subject recruitment relied upon verbal solicitation within the CCP space. The poster can be viewed in Appendix C.

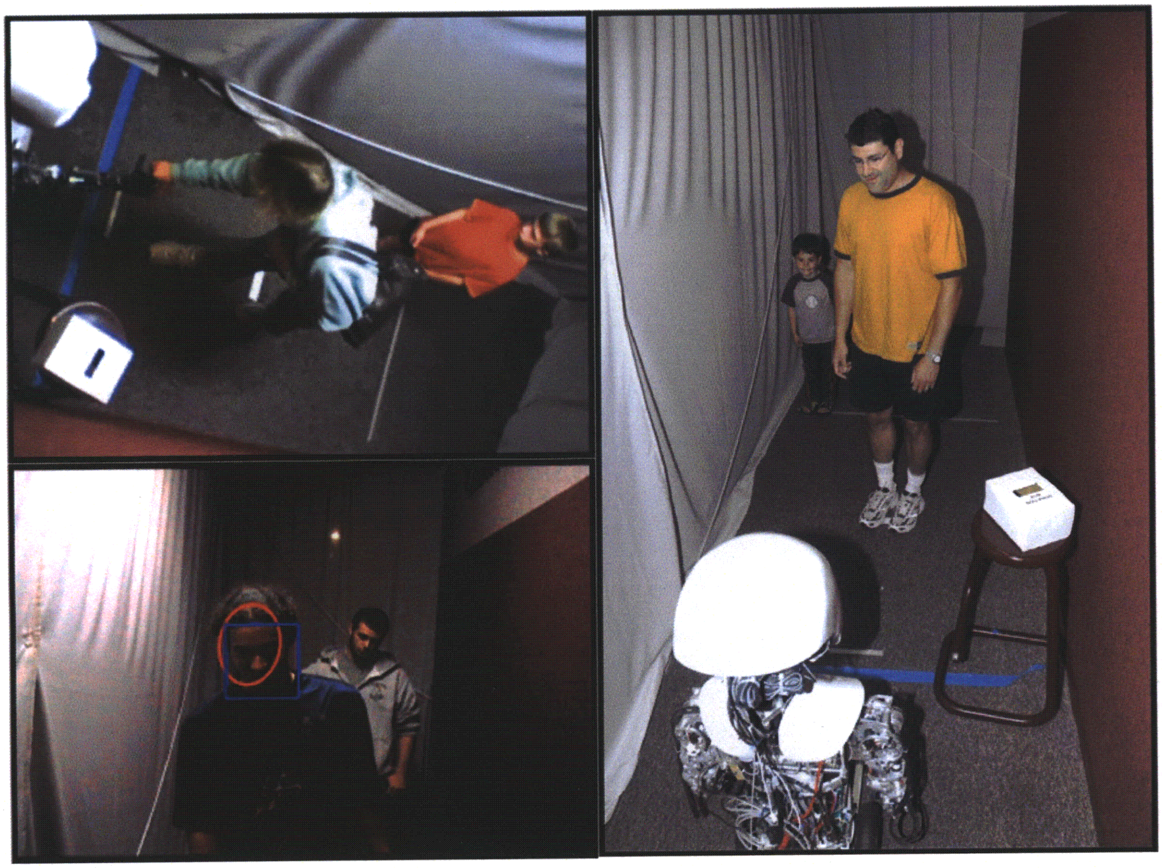

Figure 3-4: Subjects interacting with the robot. Upper left image shows a handshake as seen from an overhead camera. Lower left image shows subjects as seen from the camera used for face tracking, directly above and behind the robot's head. The right image shows the interaction space with the donation box on the subject's left side.

Mobile Dexterous Social Robot

The Mobile Dexterous Social (MDS) robot was developed as a platform for research into human-robot interaction (see Figure 3-7). Its development was led by Cynthia Breazeal of the Personal Robots Group at the MIT Media Laboratory, and contributors include the Laboratory for Perceptual Robotics at the University of Massachusetts at Amherst, Xitome Design, Meka Robotics, and digitROBOTICS. The purpose of the MDS platform is to support research and education goals in human-robot interaction and mobile manipulation with applications that require the

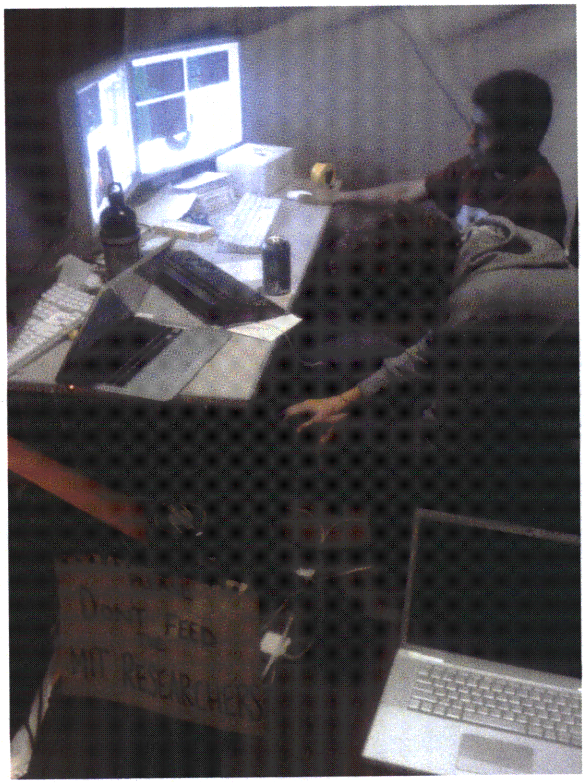

Figure 3-5: The robot operator space, showing two of the MDSMOS team members hard at work.

integration of these abilities.

The robot is unique in that it posses a novel combination of mobility, dexterity and facial expressiveness. This combination grants it a greater potential for sophisticated roles in HRI. Its total height is approximately 48 inches, and its weight is 65 lbs with no external batteries. The mobile base was originally designed as a two wheel dynamically balancing platform, though it has been repurposed by adding a head and arms. For the present study, support wheels were added, allowing it to be statically stable. The face had 17 degrees of freedom (DOF), including gaze, eyelids, eyebrows, and a jaw enabling a wide range of facial expressions (see Figure 3-6). The neck includes an additional 4 DOFs. The upper arm and shoulders each have 4 DOFs, combined with 1 DOF for the hip rotate. The forearms and hands each have 4 DOFs enabling grasping and manipulation of objects.

MDSMOS Team

The group of students running the study, nicknamed the *MDSMOS team*, included three MIT undergraduates, a high school student, and the author. The study was run seven days a week for a continuous period of six weeks, with the only exceptions being days that the robot required extensive maintenance. The five members of the MDSMOS team were scheduled such that there would be two members present on any given weekday, and three on the weekend whenever possible.

One member of the team was stationed inside the robot control area, which was sectioned off from the study area and the exhibit space by two curtains. It was the team's responsibility to run the study control interface, monitor the robot for malfunctions, handle the donation money, as well as count the donations after the subject left the study space. The other member of the team was responsible for acquiring subjects for the study, showing them to the questionnaire, and answering any questions. Details about the subject recruitment procedure can be found in Appendix B.

In order to present an aura of organization, professionalism and consistency, all members of the MDSMOS team wore identical t-shirts with the MIT logo. This dress code helped to distinguish the team members from the museum visitors as well as the museum staff. It also added a degree of credibility, helping to reduce any skepticism concerning the legitimacy of the experiment.

Study Control Interface

The study control interface was designed to be made as simple and straightforward in terms of handling the operation of the study. Image 3-8 shows the graphical interface, with the available controls on the left side, and the 3-D robot visualization on the right side. The controls allowed the operator to specify the subject number, and choose when to begin and end the interaction. The specific variables being tested were enabled or disabled using the toggle buttons [3].

Before starting a session, the operator would have to first assign the appropriate variable configuration and then press the *Load* button. The *Load* operation first created the log file, which was used to store all data relevant to the study. Initially, the variable configuration is written to the log file as well as a time stamp for the study load time. Once loaded, the operator would be prompted to enter the number of minors and adults accompanying the subject. At this point the robot would begin its idle procedure, which consisted of slow and seemingly random movements, including gazing from side to side and simulated breathing.

Once the subject and any additional visitors were in the space, and the MDSMOS team member had left, the robot operator would push the *Start* button to begin the study. For the interactive phase of the study, after each question that the robot asked, a pop-up window appeared prompting the robot operator to signal the subject's response. Once the subject replied, the interface would be notified, and the robot would continue with the educational performance. In the case of the handshake condition, the robot would reach out its hand at a set time, but would wait for the signal from the robot operator to continue with the ending portion of the shake.

Following the educational performance, a window would appear, prompting the robot operator to determine and enter the donation amount. Once entered, that subject session would be officially completed, any final data would be recorded to the log file, and the interface would return to its non-active state.

3.2.3 Protocol

Subject Recruitment

Great effort was made to make the recruitment of subjects as consistent and controlled as possible. MDSMOS team members followed a recruitment script (which can be

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[3] The perceived autonomy variable was not present in the interface, because it had no effect on the operation of the robot

found in Appendix B) , and all members were monitored by the author during a number of practice trials to ensure adherence to the standard procedure.

The recruitment process would begin when museum visitors in the CCP space were approached by a member of the MDSMOS team and asked "Would you like to see one of MIT's latest robots?" Barring a negative response to the initial inquiry, visitors would hear the standard recruitment script. If, after hearing the script, the potential subject was still interested, they would be handed a consent form to sign, and told to take their time. The team member would then step away from the subject, creating a private space to read over the consent form. Once completed, the subject would typically approach the team member with the signed consent form, at which point the subject would be ready to participate in the study. The subject would then be led to the entrance of the study space and handed their five dollars. After receiving their five dollars the subject would be asked to stand at a position in front of the robot designated by a piece of white tape. Any visitors joining the subject during the study would be asked to stand behind a white line at the back of the space, and to keep any communication between each other to a minimum.

Once the subject and any additional museum visitors were situated inside of the space, the team member would leave the space, closing the curtain behind them. The curtain was attached on either end of the wall using a series of magnets, ensuring that there was no exposure to the outside space which might violate a perception of privacy. The robot operator, monitoring the space through a color video camera concealed behind a curtain above the robot's head (see Figure 3-4), would start the study as soon as the team member was out of the space.

Donation Protocol

During the recruitment process the subjects were told that they would be receiving five dollars as compensation for participating in the study. They were also told that the robot may ask for a donation and it was their choice to give any of the money away. The donation money was presented as five one dollar bills attached to an MDS robot sticker with a paperclip. An indication of each subject's subject number was placed on the back of the sticker. This package was used to identify and refer the subject to begin filling out the questionnaire after the interaction with the robot.

The donation box was approximately the size of a shoe box, and was positioned at waist height between the subject and the robot, against the wall, on the subject's left side (see Figures 3-4 and 3-3). It was completely white except for "Donation Box" written in large black lettering on the top of the box. Also on the top of the box was a large slit, through which subjects would be able to insert their donations. Because the box was emptied after each subject, the box would always appear empty if the subject peered into it.

Robot Educational Performance & Persuasive Appeal

The robot educational performance consisted of two major parts. In the first part, the robot provided a brief explanation of its hardware and software systems and gave a general overview of what its capabilities were. This included a short discussion of its sensors and how they relate to human senses. The second phase consisted of the persuasive appeal in which the robot argued that subjects should donate money to the MIT Media Lab in order to help alleviate the issue of a global uneven distribution of technology. A complete transcript of the educational performance can be found in Appendix A.

During the persuasive appeal phase, subjects were invited to make a donation to MIT Media Lab research. They were then told that any money they have left was theirs to keep. At the end of the interaction, subjects were asked by the robot to fill out a short questionnaire.

Some aspects of the performance were modified depending on the condition being tested. For example, in the case of the handshake, there would be a pause in the script as the robot waited for the subject to reciprocate the handshake gesture. These condition specific changes can be found in Chapter 4, in the specific section for that condition.

Post-Study Questionnaire

Directly after depositing their donation (or moving to leave the space), subjects were met by a team member at the entrance/exit of the study space. They would then be led to the questionnaire table and invited to sit down. The questionnaire table was positioned in a corner of the CCP space and equipped with three small touch screen computers (see Figure 3-9), each with an identical interface [4]. The subject or the team member would enter the subject number printed on the back of the MDS sticker included with their donation money into the first page of the questionnaire interface. Once the subject number was entered, the subject would be presented with a series of multiple choice questions (see Appendix E), each on a separate page. The beginning of the questionnaire included personal questions regarding age, gender, race, etc., which were followed by the dependent attitude measures listed in Section 3.2.4.

3.2.4 Dependent Measures

A total of seven dependent measures were used for this experiment.

- Donation
- Credibility
- Trust
- Engagement
- Happiness

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[4] The touch interface was difficult for some people to use, so it was replaced with a traditional mouse interface about two weeks into the study.

- Number of Questions Answered
- Time Spent on Questionnaire

As previously discussed, the subject's donation amount was used to measure the persuasiveness of the robot. It was assumed that persuasion could be measured by the robot's success in obtaining compliance to a request. As discussed in Section 3.2.3 the subject received five one dollar bills and had the option of depositing any amount of that money into a donation box positioned between the subject and robot.

Credibility, trust, engagement, and happiness were measured using standard Likert scales administered in the post-study questionnaire. All scales used in the questionnaire can be found in Appendix E.

The number of questions answered and the time spent on questionnaire measures were ascertained after the study from information automatically stored for each questionnaire. Because the robot makes an explicit request for subjects to fill out the questionnaire after the interaction, it was believed that the time spent and number of questions completed would be representative of the subject's willingness to comply with the robot's request.

3.3 Summary

This chapter explained in detail the setup and procedures for the six week study conducted at the Museum of Science in Boston during the summer of 2008. As discussed, the goal of the study was to understand how certain changes in the MDS robot's appearance and behavior might alter subject's compliance with a request. The independent variables in this study included robot gender, touch, interpersonal distance, and perceived autonomy. To test compliance, the robot requested a donation from museum visitors, who had previously received five one dollar bills as compensation for participating in the study. A post-study questionnaire was also used to measure subjects' attitudes toward the robot, along dimensions known to be related to persuasiveness. In the next chapter we continue with a detailed presentation of the results of the study.

Figure 3-6: Example facial expressions for MDS robot.

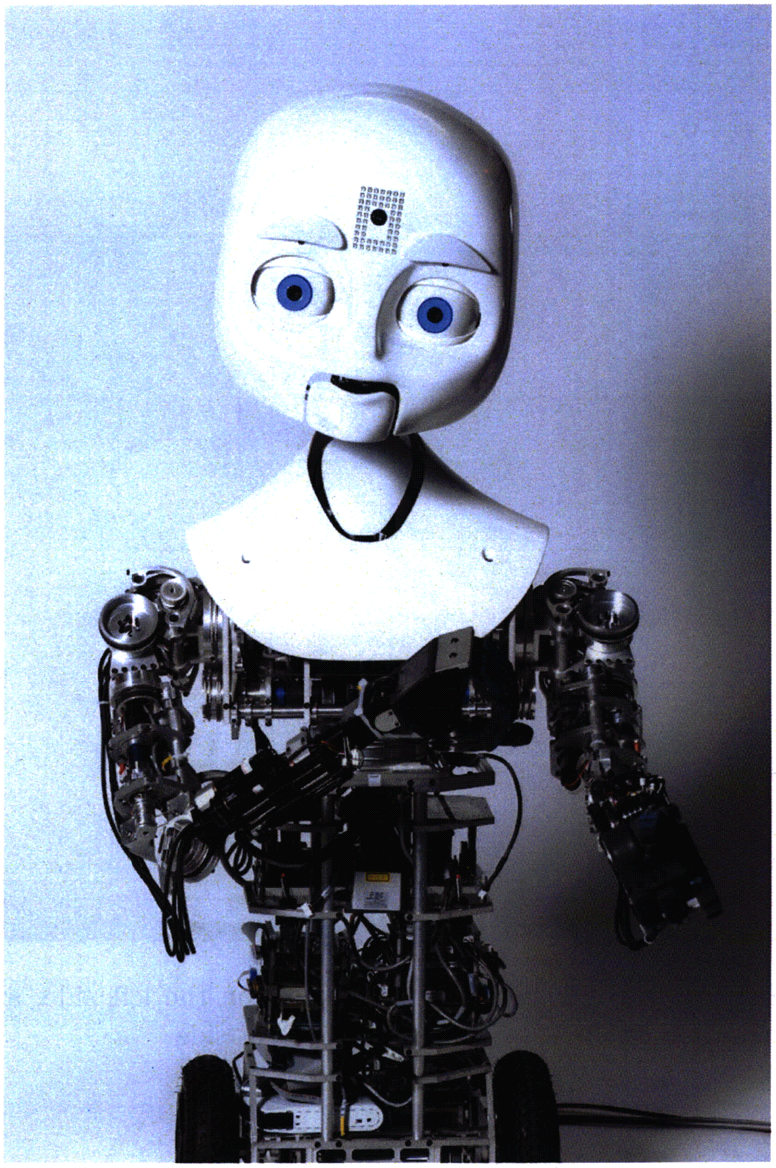
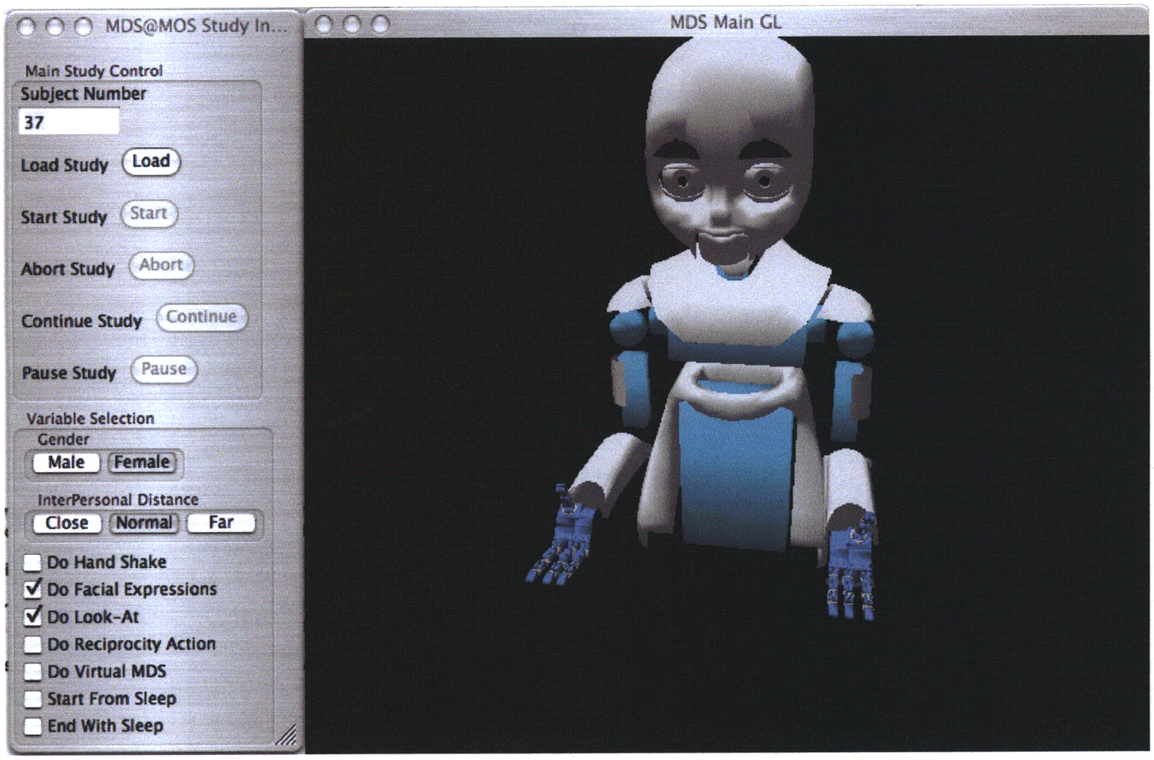


Figure 3-7: MDS robot showing the two wheel balancing base.



Subject Number
37

☐ Do Hand Shake
☑ Do Facial Expressions
☑ Do Look-At
☐ Do Reciprocity Action
☐ Do Virtual MDS
☐ Start From Sleep
☐ End With Sleep

Figure 3-8: Study Control Interface with controls on the left side, and a real-time virtual representation of the MDS robot on the right side.

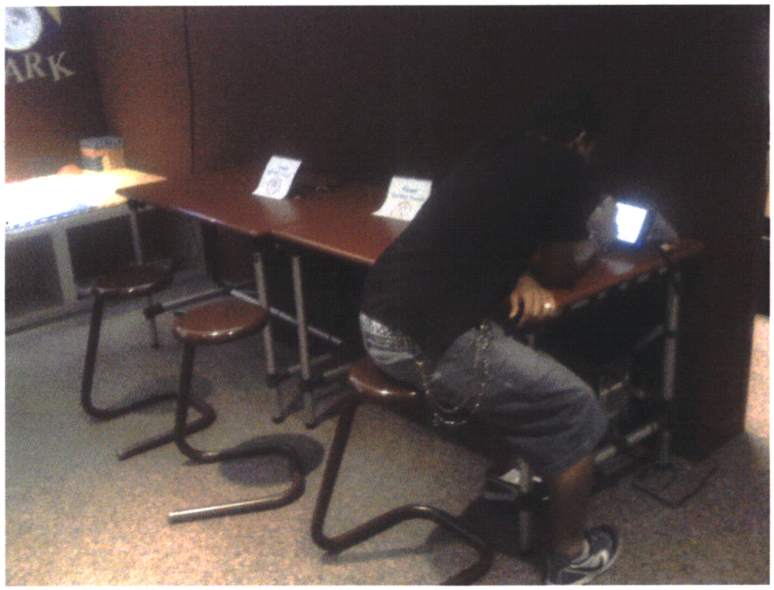


Figure 3-9: Questionnaire station which included three small touch screen where subjects could fill out the questionnaire after the robot interaction.

Chapter 4

Experiment Results

This chapter presents the results of the Museum of Science study, organized into four sections, based on the four conditions of the study. The first section (4.1), presents the results of the robot gender condition in which the robot was portrayed as either male of female depending on the recorded voice used. The second section (4.2), presents the results of the perceived autonomy condition in which the subject was led to believe that the robot was not autonomous, but was in fact completely controlled by the robot operator. In the third section (4.3), the touch and robot gender conditions, which were crossed in a factorial design, are described. The touch gesture was in the form of a handshake initiated by the robot, and the gender, as in Section 4.1, was changed using a gendered voice recording. Finally, the interpersonal distance condition (4.4), in which subjects were positioned at an abnormally close distance to the robot, is discussed.

4.1 Robot Gender

In this condition the gender of the robot was changed from male to female. For many of the conditions in the interactive portion of the experiment, the robot gender was held constant at male, unlike the non-interactive portion of the experiment where the gender was only female. Because of this, the male condition is considered to be the control, or normal condition. The only difference between the male and female robot is the gender quality of the voice. For this experiment a human voice recording was used, rather than computer synthesized speech.

The results of this condition show a general trend of an interaction effect between subject gender and robot gender. Men tended to rate the female robot more positively and donated more than they did to the male robot. Women, conversely, tended to rate the male robot more positively and donated more money.

4.1.1 Method

Participants

There were 87 subjects that actually interacted with the robot in the robot gender condition. All 87 were counted for the donation measure, however because not all subjects finished the questionnaire, other measures have fewer participants. Of the 87 participants, 56.3% were male ($n = 49$) and 43.7% were female ($n = 38$). There was an average of .826 people ($\sigma = 1.10, min = 0, max = 5$) accompanying the subject during the robot interaction.

Because characteristics such as age, education, race, technical knowledge, and knowledge of the MDS were randomly distributed throughout the conditions, and are not used here for analysis, these statistics are presented only once in the general study overview.

Design

This experiment was based on a 2 (robot gender: male vs. female) × 2 (subject gender: male vs. female) between subjects factorial design. The case of whether or not the subject was alone is also considered, producing a 2 (robot gender: male vs. female) × 2 (subject gender: male vs. female) × 2 (subject alone: alone vs. not alone) between subjects factorial design.

Setup

Fundamentally the setup for each gender was identical. The only difference was the audio that was played. This change in audio was controlled by the study control interface which requires that the robot always be in one of two states: male or female. Effort was made to not only match the script exactly, but to match the general timing and feel of the two scripts. Because the female voice was recorded first, the male voice artist actually listened to the female recording while recording the male version.

There was only one minor change in the script which should be noted. In the female script, the final line of the persuasive appeal reads "Any money left in the envelope is yours to keep." In the male version of the script this line was changed to "Any money you have left is yours to keep." The reason for this change was an early attempt at addressing the issue of the bimodal distribution of donations. Because the money was originally distributed in an envelope, it was felt that the envelope was symbolically unifying the five one dollar bills into an inseparable group. The proposed solution (which seemed to have little effect), was to instead use a paperclip, which joined the money along with an MDS robot sticker with the subject number written on the back. The intention of the change was to generalize the script in the hopes of preventing participants from searching for a non-existent envelope.

Protocol

There was no deviation in standard protocol for this measure. It should be noted though, that care was taken not to expose subjects to more than one gender. This could happen if the gender was switched frequently (i.e. every subject), because the audio from the robot was audible from the questionnaire station. Because of this, we tended to run a single gender in large groups, separated by days, or long pauses during the day.

4.1.2 Results

A general pattern appeared to emerge in the data, correlating the gender of the robot with the gender of the subject. Across subject gender (see Figure 4-1), there was very little significance to the data, although incorporating the subject gender into the analysis revealed an interesting interaction effect. Across every condition participants tended to rate the robot of the opposite sex higher than the robot of the same sex. As Figure 4-2 shows, men tended to prefer the female robot while women (see Figure 4-2) tended to prefer the male robot.

The significant results from this condition included a three way interaction (robot gender, subject gender, subject alone) indicating that women showed a same-sex preference when accompanied (donating more often to the female robot), but a cross-sex preference when alone (donating more often to the male robot) as can be seen in Figure 4-3. Men also showed a strong cross-sex preference when alone (donating more often to the female robot), but showed almost no difference when accompanied (see Image 4-3). We also see a strong general tendency for men to donate more often to the female robot, while women don't show a strong preference.

Men tend to find the female robot to be significantly more credible, while women find the male robot more credible. The same interaction occurs with trust, though this effect is predominantly caused by men reporting more trust of the female robot.

Donation

The continuous donation measure was not found to vary significantly across conditions, though it does seem to conform to the interaction effect between subject and robot genders found across measures, which is clearly seen in Figure 4-2. Though not statistically significant, men tended to donate more money to the female robot, ($M = \$2.78, \sigma = 2.34$), while donating less money to the male robot ($M = \$1.96, \sigma = 2.34$). Women showed the opposite preference, donating more money to the male robot ($M = \$2.61, \sigma = 2.39$), and less money to the female robot ($M = \$2.47, \sigma = 2.23$).

Table 4.1: Summary of results for the robot gender condition.

Donation	Three way interaction between robot gender, subject gender, subject alone ($p < .011$). When robot is female, women donate less often when alone, men donate more often when alone. When robot is male, women donate more often when alone, men change very little. Overall, Men donate more often to the female robot ($p < .027$). Women show little preference.
Credibility	Men rate female robot as more credible, women rate male robot as more credible ($p < .029$).
Trust	Men rate female robot as more trustworthy, women rate male robot as more trustworthy ($p < .056$)
Engagement	Men rate female robot as more engaging, women rate male robot as more engaging ($p < .045$). Female robot is more engaging ($p < .05$).

A three way ANOVA which included the condition of whether or not the subject was alone did not suggest any significant interactions.

Looking at the simplified binary form of donation (gave-nothing vs. gave-something) a two way ANOVA between gender subject and gender robot reveals a notable main effect due to the gender of the robot ($p < .068$) suggesting that the female robot is more likely to receive a donation than the male robot.

A three way ANOVA, which adds whether or not the subject was alone to the previous analysis, shows a significant three way interaction between all independent variables ($p < .011$). In the case of the female robot, women donated less when alone, while men donated more when alone. In the case of the male robot women donated more when alone, while men also donated more when alone, but only slightly (see Figure 4-3).

We also see a minor interaction between gender robot and gender subject ($p < .110$), which, as seen before, shows a cross-sex preference where men donate more often to the female robot and women donate more often to the male robot.

Separating the cases into two groups by subject gender, we see that the effect

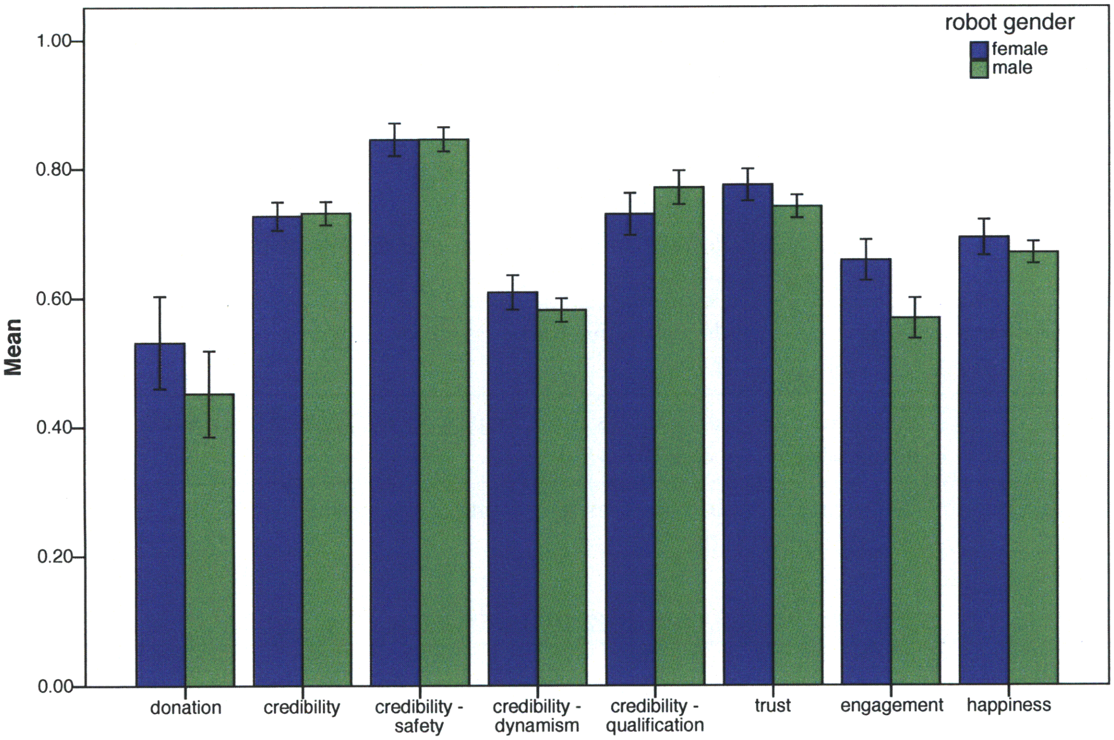


Figure 4-1: Gender of robot across subject gender. Error bars indicate +/-1 standard error.

of robot gender on the donation behavior is much more pronounced in men than in women. A t-test run on the male group, with robot gender as the independent variable, shows a significant tendency ($p < .027$) for men to donate more often to the female robot. Women, on the other hand, don't seem to be as strongly influenced by the robot gender ($p < .610$).

Collapsing over all conditions, and looking only at a t-test run with robot gender as the independent variable, we see that the female robot receives donations significantly more often than than the male robot ($p < .044$).

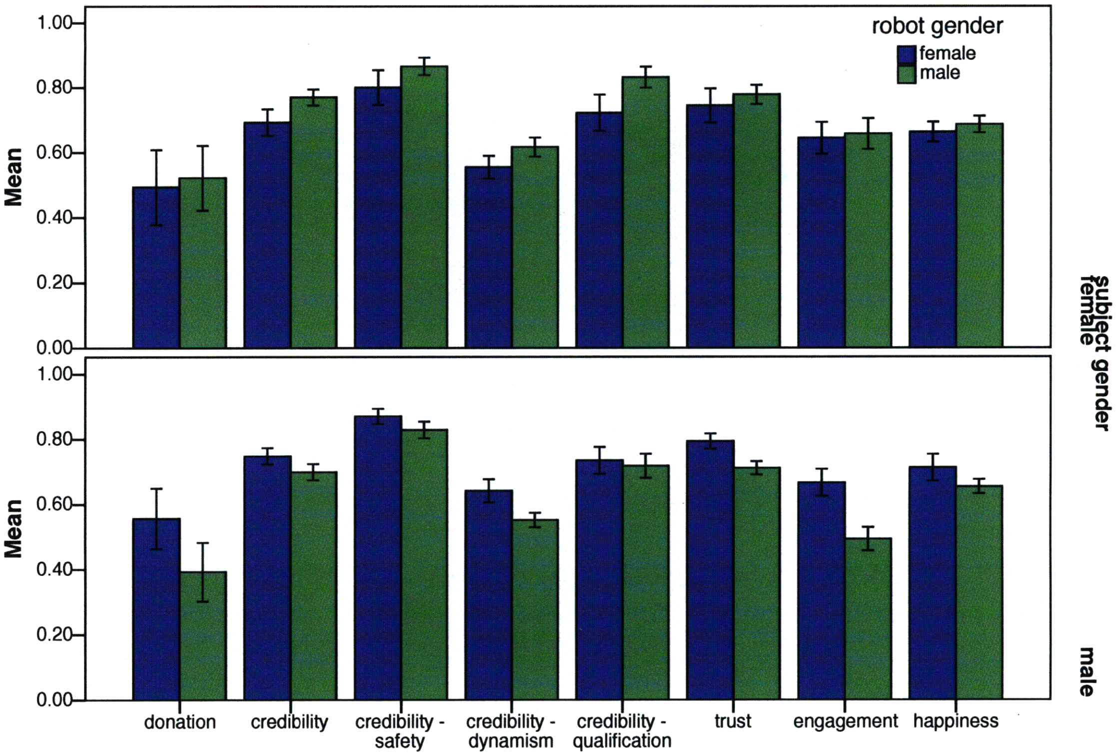


Figure 4-2: The effect of robot gender on male and female subjects. Error bars indicate +/-1 standard error.

Credibility

There was no notable relationship between this measure and the number of people accompanying the subject, so it made sense to collapse over that condition and focus on the two way anova (robot gender vs. subject gender).

Overall credibility, as well as all the three dimensions of credibility show at least a marginally significant interaction effect between the gender of the subject, and the gender of the robot. In all cases, men tended to rate the female robot as more credible, while women rated the male robot as more credible. A two way ANOVA between the genders reveals a significant interaction effect ($p < .029$) for overall credibility. This effect also held true along the three dimensions of credibility: dynamism ($p < .017$), safety ($p < .087$), and qualification ($p < .132$). Neither robot gender, nor

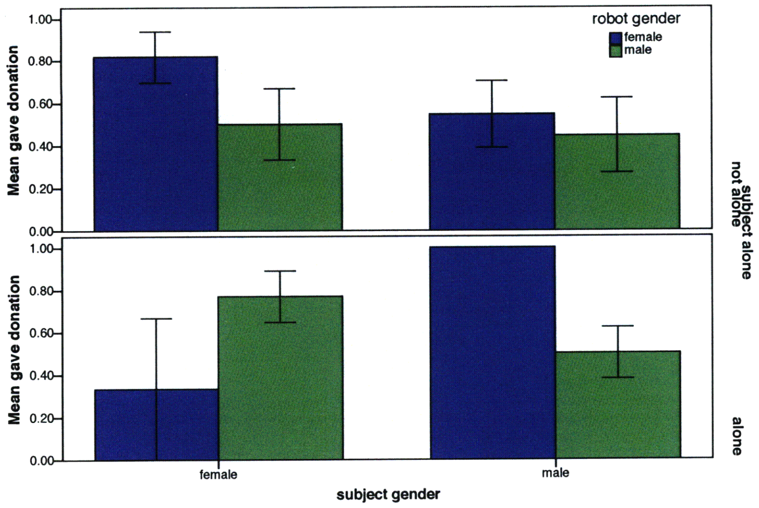


Figure 4-3: The effect of robot gender, subject gender and whether or not the subject was alone on donation frequency. Error bars indicate +/-1 standard error.

subject gender showed a main effect associated with those variables. This result is an important validation of the donation measure and overall persuasiveness as correlated to gender.

Trust

There was no notable relationship between this measure and the number of people accompanying the subject, so it made sense to collapse over that condition and focus on the two way anova (robot gender vs. subject gender).

Trust, as with the other measures in this condition, showed an interaction effect between the gender of the robot and the gender of the subject. Men tended to report that the female robot was more trustworthy than the male robot. Women, conversely, reported that the male robot was more trustworthy than the female robot ($p < .056$). The main effect of both robot gender and subject gender show very little statistical significance.

Splitting the cases into two groups by subject gender shows that it is men who are predominantly effected by the change in robot gender. A t-test run on each group shows that men were significantly more trusting of the female robot ($p < .011$), while women were only slightly more trusting of the male robot ($p < .551$).

Engagement

The interaction effect between human gender and robot gender stays strong as we examine reported engagement. As expected, men reported that the female robot was significantly more engaging, while women reported that the male robot was significantly more engaging ($p < .045$). Unlike other measures, engagement suggested a possible main effect with both independent variables. Reports indicate the female robot is more engaging ($p < .083$), and women tend to report being more engaged ($p < .126$). Indeed, collapsing over subject gender and running a t-test on robot gender, a main effect is apparent ($p < .05$), confirming that the female robot was considered more engaging.

As with the trust measure, separating the cases into two groups according to subject gender shows that men reported significantly more engagement with the female robot ($p < .003$), while women showed no significant preference for the male robot ($p < .862$).

A three way ANOVA including whether or not the subject was alone does not suggest a relationship with reported engagement.

Happiness

The results for the happiness measure were not very strong, though they do conform to the interaction effect between genders seen in other measures. The two way ANOVA reveals a minor interaction effect ($p < .192$), while showing relatively no main effect for gender robot or gender subject. The three way ANOVA does suggest a main effect for whether or not the subject was alone ($p < .068$), as well as an interaction between the gender of the subject and whether or not that subject was alone ($p < .05$). Men who were alone tended to report being less happy, while women who were alone reported being happier after the interaction.

Time Spent on Questionnaire

The amount of time spent on the questionnaire does not appear to have a relationship with either of the independent variables in the two way ANOVA. The three way ANOVA does indicate a significant relationship between time spent on the questionnaire and whether or not the subject was alone ($p < .05$). As one would expect, participants who were alone tended to spend more time on the questionnaire than those accompanied friends or family.

Number of Questions Answered

There was no significant relationship revealed by the two way ANOVA, though there did seem to be a small main effect relating to the gender of the robot. Across subject genders, participants tended to answer more questions after interacting with the male robot, than with the female robot. The three way ANOVA reveals a very strong main effect for whether or not the subject was alone ($p < .001$). As expected, the average number of questions answered was significantly higher for participants who were alone.

4.2 Perceived Autonomy

The goal of the perceived autonomy condition was to test the effect of altering the level of autonomy the subject perceived the robot to have. By exposing the robot operator to the subject during the interaction, as well as explicitly telling the subject before the interaction that the robot was not autonomous was hoped to alter the subjects perception of the degree to which the robot was controlling itself.

Contrary to expectation, subjects tended to donate more money to the robot portrayed as not autonomous. Most other measures showed an interaction effect between the gender of the subject, and the perceived autonomy. Generally speaking, women rated the robot higher when they perceived it to be autonomous, while men rated the robot higher when it was portrayed as not autonomous. This effect tended to be more pronounced in men.

4.2.1 Method

Participants

There were 82 subjects that actually interacted with the robot in the perceived autonomy condition. All 82 were counted for the donation measure, but because not all subjects finished the questionnaire other measures have fewer participants. Of the 82 participants, 58.5% were male ($n = 48$) and 41.5% were female ($n = 34$). There was an average of .878 people ($\sigma = 1.09, min = 0, max = 5$) accompanying the subject during the robot interaction.

Design

This experiment was based on a 2 (perceived autonomy: autonomous vs. not autonomous) × 2 (subject gender: male vs. female) between subjects factorial design. The case of whether or not the subject was alone was also considered producing a 2 (perceived autonomy: autonomous vs. not autonomous) × 2 (subject gender: male vs. female) × 2 (subject alone: alone vs. not alone) between subjects factorial design.

Setup

In order to alter the perceived autonomy of the robot, the curtain normally separating the robot operator from the subject was lifted. This curtain normally hung directly behind the robot, thus, when lifted, the robot operator was in constant view of the subject. In addition to lifting the curtain, a 3D model of the robot moving in synchrony with the real robot was enlarged and placed to take up the entire space of a 23 inch computer monitor. This 3D model was clearly visible from the distance of the subject and was meant to add to the impression that the operator and computers were somehow involved in the control of the robot.

Under normal conditions this black opaque curtain completely conceals the robot operator from the subject. A second curtain also concealed the robot operator from the general space of Cahners ComputerPlace. Effort was made throughout the study to discretely enter and leave the robot control area, reducing curiosity as to the nature of the robot control. The intention was that only in this condition would any questions regarding the autonomy of the robot enter into the subjects' minds. The gender of the robot was male in all cases of this condition.

Protocol

The protocol for the perceived autonomy condition was altered in one crucial way. After being led to the experiment space, and told where to stand, the subject was told "This is the robot. It is not autonomous, it is controlled by the robot operator. The robot operator is sitting behind the robot." The intention of this statement was to clearly and simply convey to the subject that the robot was completely controlled by the robot operator.

Though there is no conclusive evidence for this, it is the author's opinion that the vast majority of participants would normally assume that the robot was autonomous to some degree. This opinion is based on conversations with participants as well as their general behavior towards the robot. Thus, it seems likely that in most cases clearly ruling out the robot's autonomy would alter the subject's view of the robot.

4.2.2 Results

The results of the perceived autonomy condition are in many ways surprising. The general hypothesis, that people would tend to donate more, and have a more positive view of the autonomous robot, was not entirely true, and in the case of donation was completely false. Interestingly, subjects tended to donate significantly more money

Table 4.2: Summary of results for the perceived autonomy condition.

Donation	Subjects donated less to autonomous robot, more to human controlled robot ($p < .059$).
Credibility	Women rate autonomous robot as more credible, men rate human controlled robot as more credible ($p < .06$).
Engagement	Men rate the robot as more engaging, women rate the robot as less engaging ($p < .06$).
Happiness	Men report being happier after human controlled robot, women are happier after autonomous robot ($p < .04$).

to the robot when led to believe it was not autonomous. This main effect of the perceived autonomy is only found with donation; the other measures exhibited a peculiar tendency of their own.

Excluding the donation measure, the perceived autonomy condition did not appear to elicit strong reactions. In many cases the results are not statistically significant. However, looking more broadly, interesting patterns did seem to emerge from the data. An interaction effect between subject gender and perceived autonomy seemed to be consistent across all measures, excluding donation. Men tended to rate the robot higher when they were told it was not autonomous, while women tended to rate the robot lower in this condition. This effect was much more pronounced in men than in women. Also, it is important to note that the robot was male gendered throughout this condition, and the impact of robot gender on these results is not known.

Donation

A surprising donation tendency emerged out of the perceived autonomy condition. Two way ANOVA (subject gender and perceived autonomy) reveals a marginal main effect with the perceived autonomy condition ($p < .059$). Subjects tended to donate less when the robot was perceived as autonomous, and more when they were explicitly told that the robot was not autonomous.

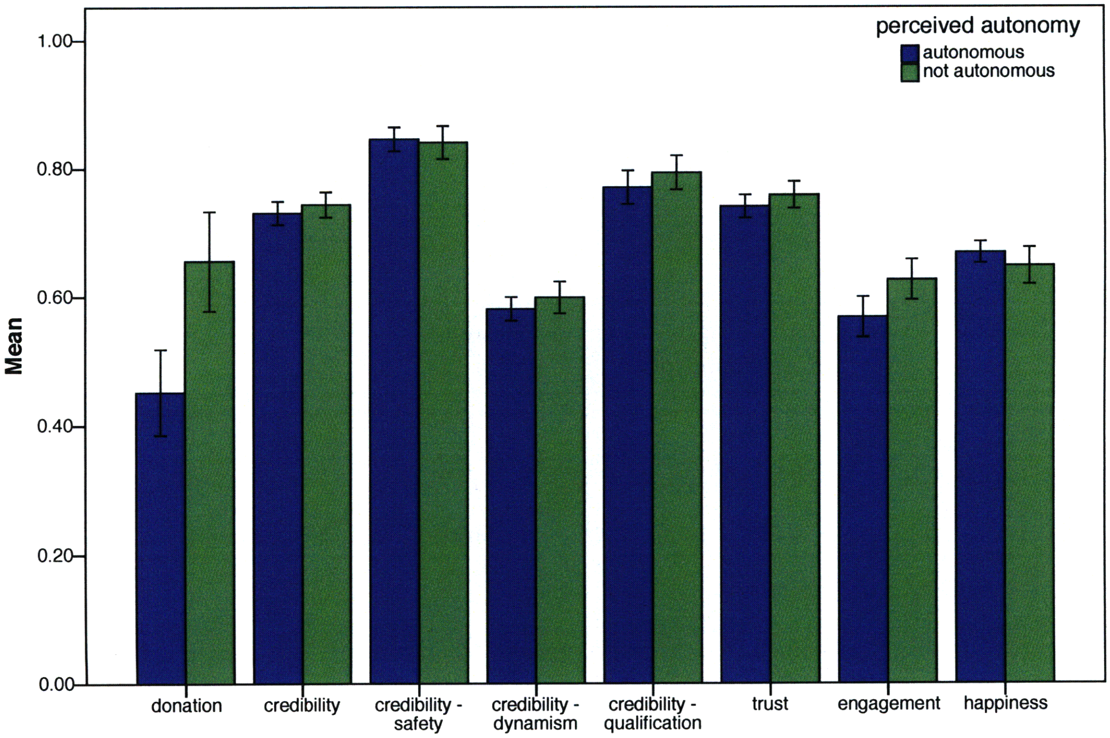


Figure 4-4: Perceived autonomy across subject gender. Error bars indicate +/-1 standard error.

The binary condition of whether or not the subject donated shows the same pattern ($p < .079$) of a non-autonomous preference. A three way ANOVA including the binary variable of whether or not the subject was alone does not show any significant relationship to that variable.

Credibility

Credibility showed an interaction effect between subject gender and perceived autonomy which will appear throughout the measures of this condition; women preferred the autonomous robot, and men preferred the non-autonomous robot. A two way ANOVA does not show this strongly ($p < .266$) though the three way ANOVA reveals a more significant effect ($p < .06$). The three way ANOVA also reveals an interaction effect ($p < .073$) between subject gender and whether or not the subject

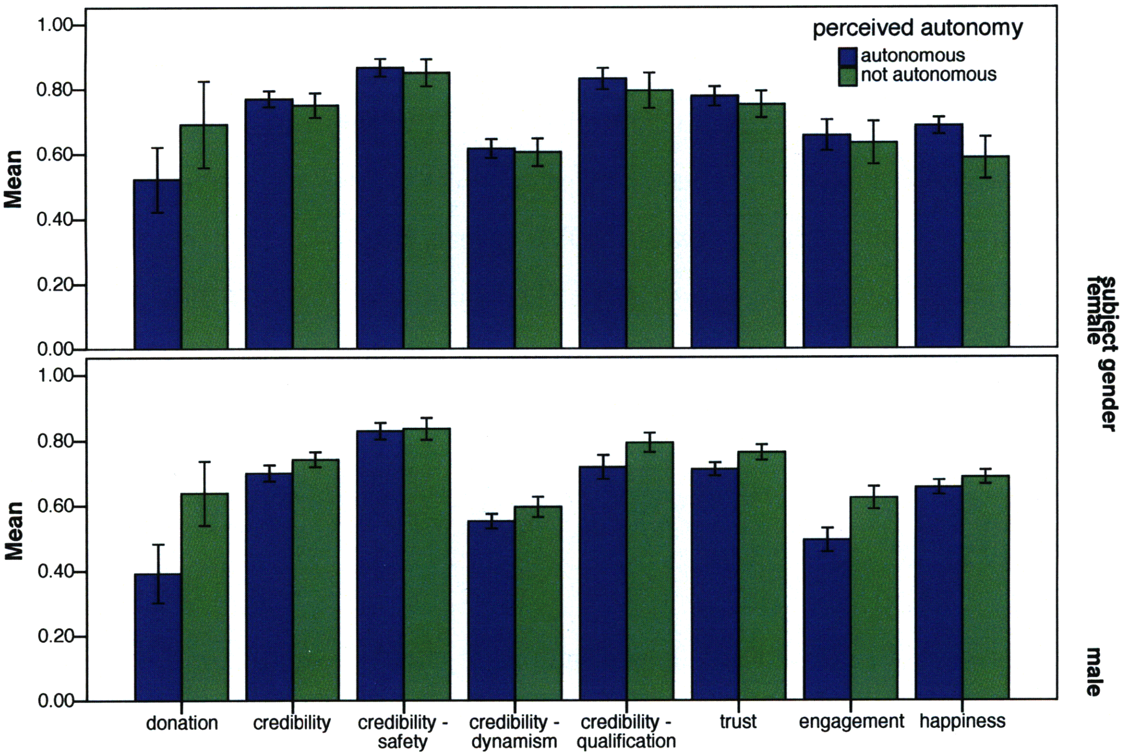


Figure 4-5: The effect of perceived autonomy on female and male subjects. Error bars indicate +/-1 standard error.

was alone. Women who were alone with the robot tended to rate it as less credible, while men in the same situation rated it as more credible. This effect is more pronounced in women than in men.

The first of the three dimensions of credibility, safety, showed no effects whatsoever, in either the two or three way ANOVA. The second dimension, qualification, showed some interaction ($p < .153$) in the two way ANOVA, and showed a statistically significant interaction in the three way ANOVA ($p < .026$). The third dimension of credibility, dynamism, showed very little difference in the two way ANOVA ($p < .377$), but became a bit more clear in the three way ANOVA ($p < .116$).

Trust

There were no statistically significant effects found in the trust measure, though we do see the subtle interaction effect between subject gender and perceived autonomy as seen in credibility. The two way ANOVA reveals this ($p < .178$) to a lesser extent than the three way ANOVA ($p < .101$). The three way ANOVA does not show an appreciable effect associated with whether or not the subject was alone.

Engagement

The three way ANOVA did not show a significant effect of whether or not the subject was alone, so it made sense to collapse over it, and focus on the two way (autonomy, subject gender) ANOVA.

There was a noticeable main effect between the gender of the subject and engagement; men tended to be less engaged with the robot than women. This effect is seen more clearly in the two way ANOVA ($p < .06$) than the three way ANOVA ($p < .125$). This is likely the strong cross-gender effect seen throughout the conditions, as the robot gender in this case was male. This main effect tends to overshadow the still present interaction effect which is stronger in the three way ANOVA ($p < .074$) than the two way ANOVA ($p < .099$).

Separating the cases into two groups based on subject gender, and looking at the effect of perceived autonomy on each group separately shows the strong male influence on the results. A t-test run on the male subject cases reveals a significant ($p < .015$) main effect of the change in perceived autonomy, indicating that men were much more engaged with the non-autonomous version of the robot. The effect for women was much less pronounced ($p < .774$), and in the opposite direction of the male subjects. This is the same pattern of interaction seen in the credibility and trust conditions.

Happiness

As with other measures in this condition, there was an interaction effect between subject gender and perceived autonomy which the two way ANOVA shows as statistically significant ($p < .04$) while the three way ANOVA shows a lesser effect ($p < .112$). What this reveals is that men report being happier after interacting with the non-autonomous robot, while women report being happier after interacting with the autonomous robot.

There does seem to be a marginal main effect of whether or not the subject was alone ($p < .065$) as shown in the three way ANOVA. Subjects that were alone tended to report being happier than subjects who were not alone. In this case it may not make sense to collapse over the subject alone condition. Thus the results from the two way ANOVA may not be as accurate as those from the three way ANOVA because they fail to take into consideration the subject alone condition.

Time Spent on Questionnaire

There was a significant main effect of the perceived autonomy condition ($p < .044$ with two way ANOVA, and $p < .045$ with three way ANOVA). Subjects of both genders tended to spend less time on the questionnaire when the robot was represented as autonomous. There were no other notable results in either the two way, or three way ANOVAs.

Number of Questions Answered

The three way ANOVA which includes the subject alone condition shows that people changed their answering behavior dependent on whether or not they were alone. A statistically significant ($p < .031$) two way interaction between the perceived autonomy condition and the subject alone condition shows that when people were alone they answer more questions for the autonomous robot, while people in groups answered more questions for the non-autonomous robot. There was also a slight main effect of the subject alone condition ($p < .112$), suggesting that people who visited the robot alone tended to answer more questions.

4.3 Touch and Robot Gender

Active touch on the part of the robot was explored in this condition. Towards the end of the interaction, the robot reached out its right hand in the gesture of a handshake. Once the robot and subject made physical contact, the robot moved its hand in an up-down-up motion and then retracted.

The results of this condition showed interesting relationships between not only robot and subject gender, but also between subjects who were alone, and those who were in groups. This suggests that touch in HRI, as in human interaction, must be understood in the social context in which it takes place.

4.3.1 Method

Participants

There were 197 subjects who actually interacted with the robot in the touch condition. Of that 198, 111 subjects were drawn from the interactive condition, while 86 were from the non-interactive condition. The decision to combine the subjects from the interactive and non-interactive conditions was made based on an analysis of the effect of interactivity. A four way ANOVA was run (touch, robot gender, subject gender, interactivity) and there were no statistically significant main effects or interaction effects associated with the interaction condition in any measure. The only measure which registered any effect with p ¡ .1 was the dynamism dimension of credibility which showed an interaction effect between subject gender and interactivity ($p < .094$).

All 197 participants were counted for the donation measure, but because not all subjects finished the questionnaire other measures had fewer participants. Of the 198 participants, 58.4% were male ($n = 115$) and 41.6% were female ($n = 82$). There was an average of 1.22 people ($\sigma = 1.57, min = 0, max = 8$) accompanying the subject during the robot interaction.

Design

This experiment was based on a 2 (robot gender: male vs. female) × 2 (touch: handshake vs. no handshake) × 2 (subject gender: male vs. female) between subjects factorial design. The case of whether or not the subject was alone was also considered producing a 2 (robot gender: male vs. female) × 2 (touch: handshake vs. no handshake) × 2 (subject gender: male vs. female) × 2 (subject alone: alone vs. not alone) between subjects factorial design.

Setup

The study control interface had a toggle which allowed the operator to specify whether or not the touch condition was enabled. If enabled, the robot would automatically reach out to shake the subject's hand at a specified time in the interaction. The robot operator had an overhead view of the robot and subject using a small video camera mounted near the ceiling. Once the handshake was initiated, the operator could use this overhead view to time the handshake procedure which could be controlled using the robot control interface.

Protocol

The touch condition involved a number of changes on the part of the robot, robot operator, and the person running the study. The study would proceed as normal, up to the point where the subject was led into the robot interaction space. At this point the subject would be told "The robot may try to shake your hand, and it is ok to reciprocate, but please be gentle." The robot would then proceed through the standard routine (which varied slightly depending on gender and interactivity), but after saying "I would like to thank you for visiting me" the robot would reach out its right hand and pause. This reach was the first of two phases in the handshake routine, only the second phase had any human intervention.

Watching through the overhead camera, the robot operator was instructed to initiate the second phase of the handshake when the subject began reaching. If, as in the majority of the cases, the subject did indeed reach, then the operator would click a designated button on the interface, otherwise, that button would be clicked after approximately 10 seconds. The second phase consisted of an up-down-up-down shaking motion, followed by a retraction. After the retraction the study would proceed as normal.

4.3.2 Results

Donation, credibility and trust all show an identical interaction effect of touch, robot gender and subject gender. This interaction reveals that, as seen in the robot gender condition, when there is no handshake, there is an opposite gender preference. Interestingly, when the robot attempts a handshake, this opposite gender preference reverses into a same gender preference (see Figure 4-6). This interaction was statistically significant in the donation condition, but only marginally significant in the credibility and trust conditions.

Uniquely, donation holds another significant interaction between the subject alone condition which actually shows the gender preference swap to be isolated to the cases where the subject is in a group. In other words, the three way interaction just discussed, is only present for the donation measure when the subject is alone. When in groups, subjects showed no robot gender preference, but rather consistently donated more money to the robot that attempted a handshake.

Engagement does not display the three way interaction seen in donation, credibility, and trust, as strongly as it shows a two way interaction between robot gender and touch. It seems that subjects of both genders are more engaged with the male robot when it shakes hands, and more engaged with the female robot otherwise.

Table 4.3: Summary of results for the touch condition.

Donation	With no handshake, subject donated more to robot of the opposite sex. With handshake, subjects donated more to robot of the same sex ($p < .013$). After handshake, subjects that were alone donated significantly less money than subject that were accompanied. When no handshake, subjects donated only slightly less when alone, than when accompanied ($p < .002$).
Credibility	With no handshake, subject rated the robot of the opposite sex as more credible. With handshake, subjects rated the robot of the same sex as more credible ($p < .088$).
Trust	With no handshake, subject rated the robot of the opposite sex as more trustworthy. With handshake, subjects rated the robot of the same sex as more trustworthy ($p < .069$).
Engagement	Subjects were more engaged with male robot after handshake, and more engaged with female robot when no handshake ($p < .004$).

Donation

The donation measure showed the same three way interaction effect between robot gender, subject gender and touch seen in most of the measures in this condition. When there was no handshake, subjects tended to donate more money to the robot of the opposite sex. The effect of touch seemed to reverse this interaction, causing subjects to donate more money to the robot of the same sex when that robot attempted to shake their hand. This interaction effect is statistically significant ($p < .013$) when analyzed using a three way ANOVA between robot gender, touch and subject gender. But perhaps this result should be considered with caution, because of the strong main effect of the subject alone condition.

The main effect of whether or not the subject was alone is clearly seen in a four way ANOVA which adds the subject alone condition to the previous three way ANOVA ($p < .003$). As expected, subjects tended to donate more money when accompanied. There was an equally significant two way interaction between subject alone, and the touch conditions ($p < .002$). After the robot attempted a handshake, subjects who were alone tended to donate less money ($M = \$.169, n = 29$) than those that were

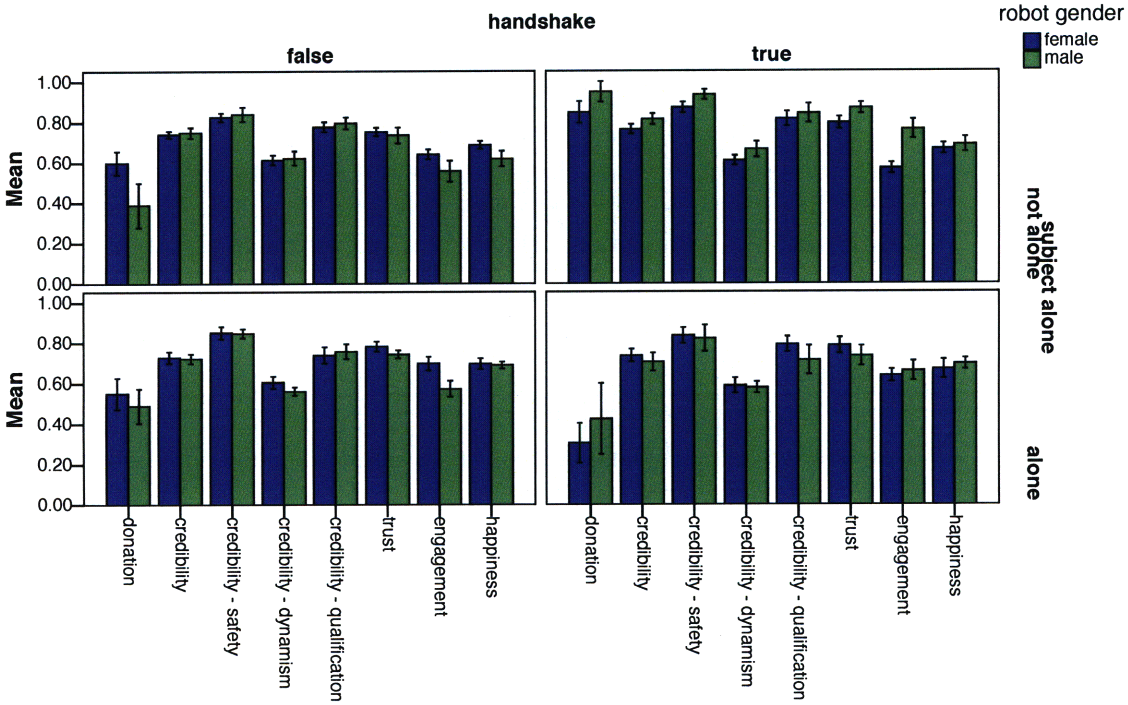


Figure 4-6: Effect of touch and robot gender and subject gender on all measures. Error bars indicate +/-1 standard error.

accompanied ($M = \$4.3, n = 33$). This large donation difference is not found when there was no handshake. In this case subjects donated only slightly less when alone ($M = \$2.59, n = 59$) than when they were not alone ($M = \$2.73, n = 74$).

When the cases are separated into two groups (subjects that were alone, and subjects that were not alone) and analyzed separately, we see that the presence of people significantly alters the relationship between gender and touch. Running a three way ANOVA (touch, robot gender, subject gender) on the cases where the subjects were alone shows the three way interaction that we saw previously ($p < .05$) (see Figure 4-7). Interestingly, the same three way ANOVA run on the population of subjects that were not alone, shows almost no three way interaction effect ($p < .87$) but rather a highly significant main effect of the touch condition ($p < .001$) (see Figure 4-7). Apparently, when the subject is alone, a complex gender dynamic exists which is not present when the subject is accompanied by others.

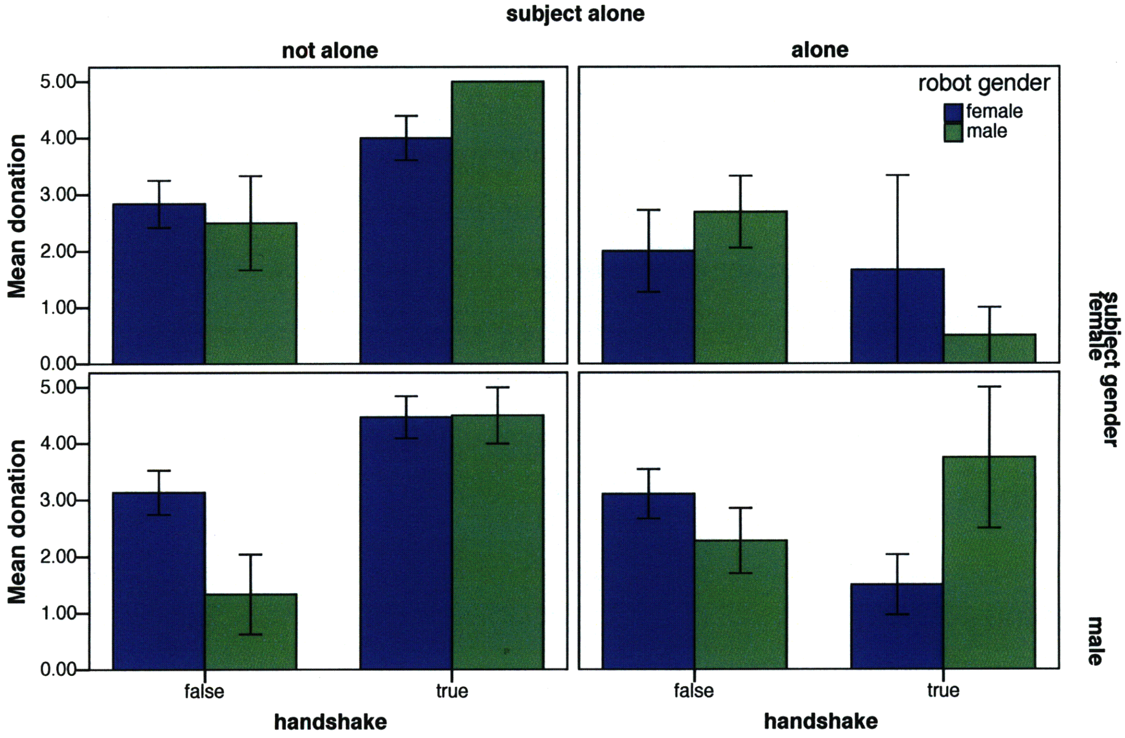


Figure 4-7: Effect of touch, robot gender and subject gender on donation behavior. Error bars indicate +/-1 standard error.

Looking at the binary condition of whether or not subjects donated anything, we see very similar behavior to the general donation measure. The three way ANOVA reveals the same three way interaction between touch, robot gender and subject gender ($p < .008$) seen previously. The analysis also reveals that subjects tend to donate more often to the female robot ($p < .026$).

The four way ANOVA shows the same main effect of the subject alone condition ($p < .003$), again suggesting that subjects donated less often when alone. We also see the same highly significant interaction effect between touch and the subject being alone ($p < .001$), indicating that after a handshake, subjects who were not alone donated more often (97.0% of the time) than subjects who were alone (41.4% of the time). When there was no handshake, there was almost no difference, and subjects who were alone, as well as those who were accompanied donated 72.9% of the time.

A significant interaction between touch and robot gender, which was not seen in the general donation measure, is apparent in the binary condition of donation ($p < .044$). This interaction shows a tendency to donate only slightly more often to the female robot when there was a handshake (female: 72.0% vs. male: 66.7%), but significantly more often to the female robot when there was no handshake (female: 83.1% vs. male: 56.0%).

The effect of the three way interaction between touch, robot gender, and subject gender is not as strong with the four way ANOVA ($p < .059$), as it was in the three way ANOVA ($p < .08$).

Credibility

A four way ANOVA which includes touch, robot gender, subject gender and subject alone, did not show any significant main effect or interaction effect associated with the subject alone condition. Collapsing over this condition, and running a three way ANOVA reveals a marginally significant interaction effect between touch, robot gender and subject gender ($p < .088$). As in the donation measure, this interaction manifests as a cross gender preference when there is no handshake, but a reversal, or same gender preference, when there is a handshake.

A notable exception in this three way interaction are the cases where the male robot attempted a handshake. Both subject genders rated the robot with the exact same credibility. It should be noted, that in both of these cases the number of subjects was abnormally low (6 women and 6 men paired with the male robot in the handshake condition). It is possible that with more subjects a similar trend would emerge.

The three individual dimensions of credibility exhibited varying relationships to the independent variables. The safety dimension shows a moderate interaction effect, nearly identical to that of overall credibility ($p < .085$). The qualification dimension showed a relatively insignificant interaction among the touch, robot gender and subject gender ($p < .335$) though it does show a main effect of the subjects gender ($p < .076$) where women tended to rate the robot higher than men. And the final dimension, dynamism, showed the same interaction effect as overall credibility, but less significant ($p < .113$). None of the three dimensions showed a significant interaction with the subject alone condition, so the results from the four way ANOVA are not reported here.

Trust

The three way ANOVA reveals the exact same interaction effect between touch, robot gender, and subject gender, seen in other measures of this condition ($p < .087$). Though not statistically significant, the consistency of this interaction effect across measures is quite compelling.

The four way ANOVA, which includes the condition of whether or not the subject was alone, shows a significant main effect of touch ($p < .045$). It also shows the same interaction effect seen in the three way ANOVA between touch, robot gender, and subject gender ($p < .069$).

Engagement

A unique interaction between touch and robot gender comes out equally strong in both the three way and four way ANOVAs. This effect, which is highly significant ($p < .004$), shows that after a handshake attempt subjects report being more engaged with the male robot than the female robot. When there is no handshake attempt, subjects are more engaged with the female robot than the male robot. This increased engagement with the female robot was also reported in the section on the robot gender condition.

There is a small interaction between touch and the subject's gender; men are more engaged when there is a handshake, whereas women are more engaged when there is no handshake ($p < .119$).

We also see the opposite gender preference prevalent in the cases without touch competing with the three way interaction between touch, robot gender and subject gender. The result is that we see a weak but global, cross-gender correlation where men are more engaged with the female robot, while women are more engaged with the male robot ($p < .111$). And the three way interaction seen throughout this section is extremely small ($p < .193$).

Happiness

Neither the three way nor four way ANOVAs show any significant results. Even the three way interaction between touch, robot gender and subject gender proves to be nearly nonexistent ($p < .357$).

Time Spent on Questionnaire

Surprisingly, the average time spent on the questionnaire does not appear to be at all related to whether or not the subject was alone. Rather, there seems to be a significant main effect of the gender of the robot where people spent more time on the questionnaire after interacting with the male robot as shown by the three way ANOVA ($p < .05$).

The two way ANOVA also reveals a couple less significant effects. The most notable of these is that men tend to spend more time on the questionnaire than women ($p < .105$).

Number of Questions Answered

Unlike the time spent on questionnaire measure, whether or not the subject was alone does seem to change the number of questions answered as revealed in the four way ANOVA. As expected, subjects who were alone when interacting with the robot tended to answer more questions on the questionnaire ($p < .062$).

The four way ANOVA also shows a small main effect of robot gender where subjects tended to answer more questions after interacting with the male robot ($p < .163$). This effect is statistically significant in the three way ANOVA ($p < .05$), as it was in the time spent on questionnaire measure.

4.4 Interpersonal Distance

This condition explores the effect of decreasing human-robot interpersonal distance, on the subject's compliance to a donation request made by the robot. Expectations violations theory would suggest that if the robot was considered an attractive or rewarding agent, then the result of decreased distance would be increased compliance to the robot's request. If the robot was not in such good standing, the effect could potentially be opposite [21].

The results of this condition show that men are significantly more effected by the change in distance than women. Generally speaking though, the decreased distance seems to have had a negative effect on men, and a slightly positive effect on women. Its important to note that the robot gender throughout this condition was female, and we would have possibly seen the reversing effect of robot gender seen in other conditions had there been a male robot. It is very likely that the predominantly male response to the gender change is due to the female gender of the robot.

4.4.1 Method

Participants

There were 113 subjects that actually interacted with the robot in the interpersonal distance condition. All 113 were counted for the donation measure, but because not all subjects finished the questionnaire other measures have fewer participants. Of the 87 participants, 58.4% were male ($n = 66$) and 41.6% were female ($n = 47$). There was an average of 1.39 people ($\sigma = 1.67, min = 0, max = 8$) accompanying the subject during the robot interaction.

Design

This experiment was based on a 2 (distance: close vs. normal) × 2 (subject gender: male vs. female) between subjects factorial design. The case of whether or not the subject was alone is also considered, producing a 2 (distance: close vs. normal) × 2 (subject gender: male vs. female) × 2 (subject alone: alone vs. not alone) between subjects factorial design.

Setup

The only difference between the standard setup described in the study overview and the setup for the interpersonal condition is the position at which the subject stands during the interaction. Two pieces of tape marked the possible standing positions, and upon entering the interaction space the subject would be asked to stand at one of these two positions. The piece of tape that marked the normal distance was placed 5 feet from the approximate center of the robot. The close position was set at 2.5 feet from the robot's center.

Protocol

Upon entering the interaction space, the subject would be asked to stand at one of two positions depending on the condition. In the close condition, subjects were asked to stand at the piece of tape measured to be 2.5 feet from the robot. During the normal condition the tape measured 5 feet from the robot. There were no other differences between the close condition and the normal condition described in the study overview.

4.4.2 Results

In an attempt to increase the statistical strength of the results by adding more cases to the analysis, the non-interactive condition was combined with the interactive. Because the interpersonal distance condition was only tested during the non-interactive phase of the experiment, the shared subjects consisted only of the normal, female robot, interactive cases. Before combining the two populations, it was important to ensure that there were no main or interaction effects, caused by the interaction condition. This was accomplished by examining the results of a three way ANOVA (distance, subject gender, interactive) and a four way ANOVA (distance, subject gender, interactive, subject alone) on the combined set of cases.

The analysis confirmed that the interaction does not play a significant role in the outcome of the various measures. Only two measures showed any effect related to interaction with $p < .1$. The first was the binary condition of whether or not subjects gave money which showed a main effect of interaction ($p < .096$), where people seemed to give money more often when the robot was not interactive. And the second was happiness, which showed a three way interaction effect between subject gender, interaction, and subject alone ($p < .019$). This last analysis can be described as men reporting more happiness when they were alone with the non-interactive robot, and less happiness when they were alone with the interactive robot. Women reported more happiness when alone with the interactive robot, and less happiness when alone with the non-interactive robot.

Looking at the combined results, donation shows significant effects, but not as a result of the distance change. One interesting finding is that the donation shows an interaction effect which is completely opposite to that of the other measures. In the binary condition of whether or not subject donated money, women were most effected by the change in distance, whereas in other measures, men were significantly more effected.

Credibility shows a significant interaction effect, revealing that men rated the

Table 4.4: Summary of results for the distance condition.

Donation	Men gave more money than women ($p < .022$), and donated more often ($p < .001$). Women donated more often when alone, men donated more often when accompanied ($p < .048$).
Credibility	Men found robot more credible at normal distance, women found robot more credible at close distance ($p < .024$).
Trust	Men trusted robot less at close distance ($p < .013$), women showed little preference.
Engagement	Men were less engaged with the robot at close distance ($p < .039$), women showed little preference.

closer robot as less credible, while women rated the closer robot as more credible. This effect holds true for all three dimensions of credibility. Men also trusted the close robot significantly less, while women were less effected by the distance. Engagement exhibited the exact same pattern; men were less engaged by the close robot, while women were ambivalent. Happiness showed a reversal of this pattern, though the effect was not strong.

Donation

Three way analysis of variance (distance, subject gender, subject alone) reveals no significant effects of whether or not the subject was alone. Because of this, it made sense to collapse over this condition and focus only on distance and the gender of the subject.

A two way ANOVA between distance and subject gender shows a significant main effect of subject gender ($p < .022$) where men give more to the robot than women. It should be noted that the robot gender throughout this condition is female, and what we see here is one half of the cross gender preference seen in other conditions which include both robot genders. There is absolutely no main effect of distance ($p = .679$), and the interaction effect between subject gender and distance is relatively small

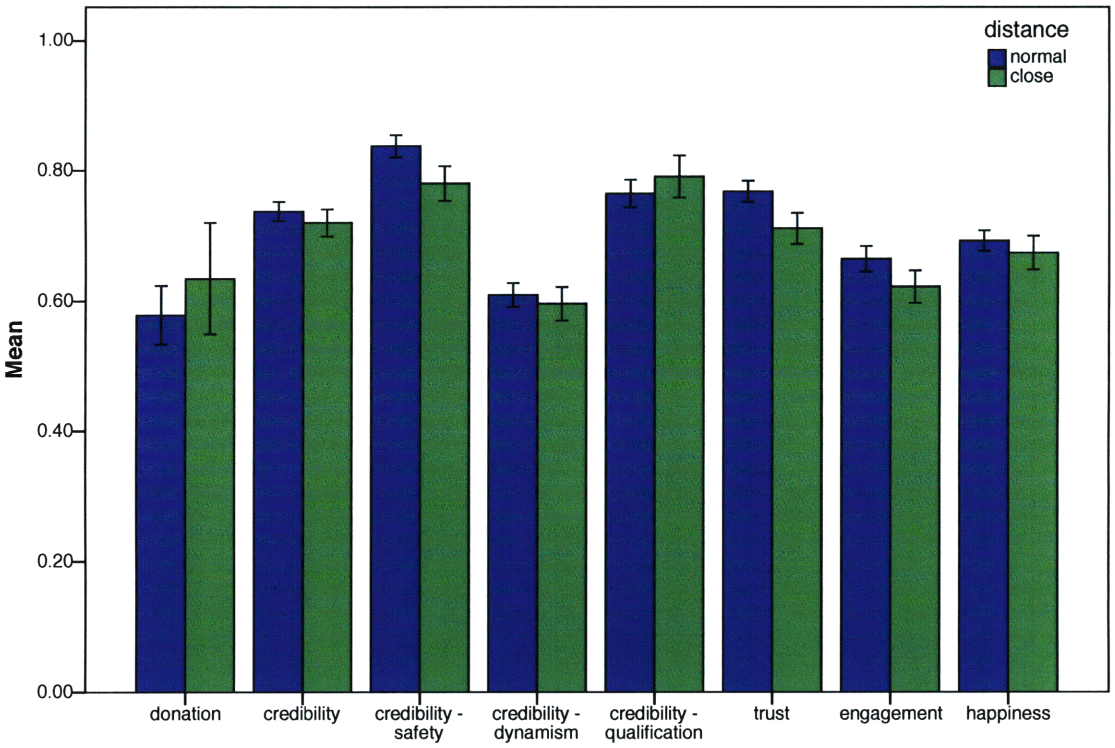


Figure 4-8: Interpersonal distance across subject gender. Error bars indicate +/-1 standard error.

($p < .267$). We do see, that men give more money to the robot that is close, while women give less money to the close robot, which is in contrast to the interaction pattern seen in other measures of this condition.

Looking at the binary condition of whether or not people gave money using a three way ANOVA shows a significant interaction between subject alone and subject gender ($p < .048$). Women tend to donate more when alone, while men tend to donate more when accompanied. Highly significant in this analysis is the main effect of subject gender ($p < .001$), where men donate significantly more often than women.

Isolating the genders and running a t-test on the distance condition shows an interesting contrast between men and women. Men showed absolutely no change in the frequency of their donations with relation to distance ($p < .959$), while women show an almost significant tendency ($p < .079$) to donate less at the close distance.

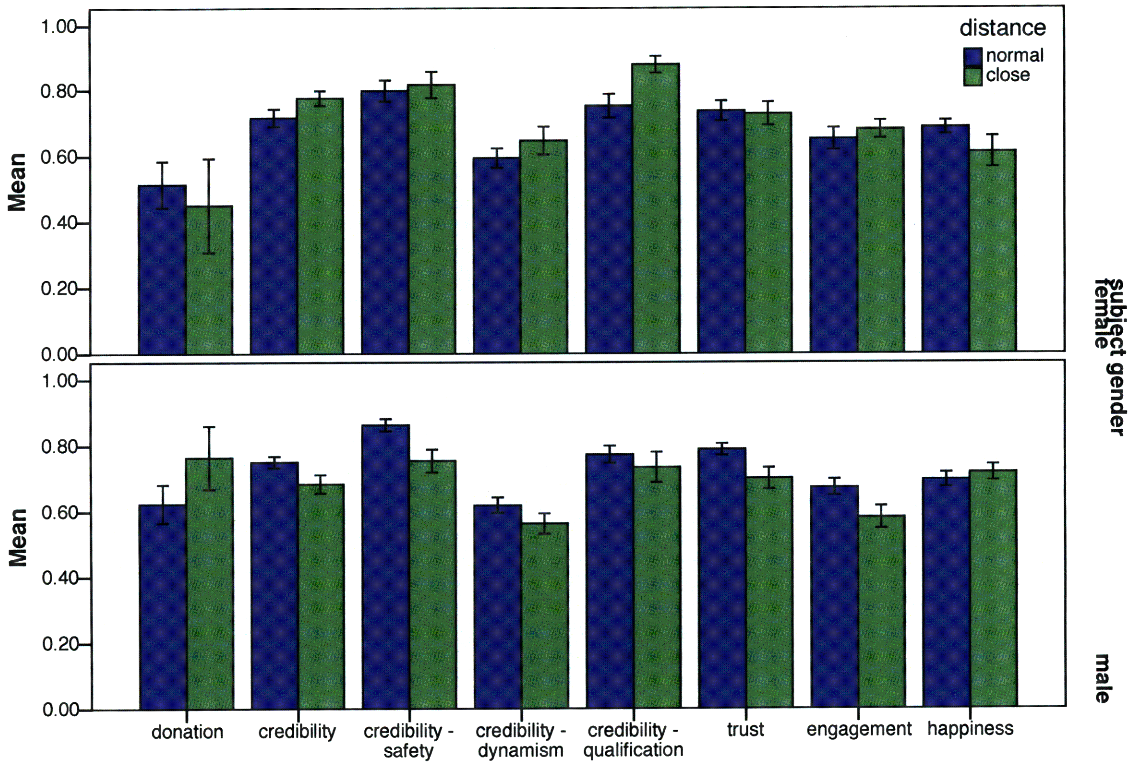


Figure 4-9: The effect of interpersonal distance on female and male subjects. Error bars indicate +/-1 standard error.

Credibility

Because there is no main or interaction effect associated with the subject alone condition, it made sense to collapse over this condition and use the two way ANOVA (distance, subject gender) as the primary method of analysis.

Here we see the interaction effect, quite strongly, which will be present in many of the measures of this condition. The interaction, between subject gender and distance, shows men finding the robot to be more credible at the normal distance, while women find the robot more credible at the closer distance ($p < .024$). This effect, as with others in this condition, is much more pronounced in men. Because the robot in this condition is female, the effects seen can be assumed to be very much robot-gender related, and would likely be swapped with a male robot. This prediction is based on previously seen robot-subject gender dynamics in this experiment.

The safely dimension of credibility shows this same interaction effect between subject gender and distance ($p < .053$). The qualification dimension shows this interaction effect to be statistically significant ($p < .044$). And the dynamism dimension shows the same interaction effect seen in the other two dimension, though slightly weaker ($p < .115$).

Trust

Collapsing over the three way ANOVA which shows no effect from whether or not the subject was alone, reveals a moderate main effect of distance ($p < .110$), revealing that the robot tends to be more trusted at the normal distance. A subtle interaction effect ($p < .110$) between subject gender and distance is also revealed, suggesting that men trust the robot more at the normal distance, while women show relatively little preference.

Examining this further by isolating the genders into two groups and running a t-test on each group reveals that men trust the robot significantly more at the normal distance ($p < .013$), then they do at the close distance. Women show very little preference with regards to distance ($p < .869$). This pattern of a male dominated dislike of the close distance, and a general female ambivalence, is also see in the credibility measure, and the engagement measure.

Engagement

The three way ANOVA which includes whether or not the subject was alone shows no main effect of the subject alone condition ($p < .981$) but does show an interaction effect with subject alone and distance ($p < .087$). This interaction effect seems to show that participants are more engaged at the normal distance when they are alone. At the close distance people are less engaged when alone.

We also see a hint of the same interaction effect seen in other measures, where men are more engaged with the close robot, and women are more engaged with the normal distance robot ($p < .129$). The two way ANOVA shows this interaction between subject gender and distance to be slightly stronger ($p < .094$).

Isolating the genders into two groups and running a t-test on each suggests that, as seen in other measures, men are significantly more effected by the change in distance than women. Men show a significantly lower reported engagement ($p < .039$) at the close distance, than at the normal distance. Women show only a slight change in the opposite direction ($p < .51$), reporting more engagement at the close distance, than at the normal distance.

Happiness

We see no effects of the subject alone condition on the happiness measure, so we felt it appropriate to collapse over this condition and focus on the two way ANOVA between distance and subject gender. The two way ANOVA shows that men report being happier after interacting with the robot at the close distance, while women report being happier after interacting with the robot at the normal distance ($p < .104$). This is a reversal of the direction of the interaction effect seen in the other measures of this condition.

We also see a main effect of gender, where men reported being happier ($p < .052$) in the close condition, and women reported being happier in the normal condition.

Time Spent on Questionnaire

There were no results from the time spent on questionnaire measure with $p > .2$ in either the two or three way ANOVAs. These results will not be included here, but can be found in the appendix.

Number of Questions Answered

There seems to be a moderate main effect of distance with respect to the number of questions answered ($p < .075$) which resulted in people answering more questions after interacting with the robot at the closer distance.

4.5 Notes on the Donation Measure

There was not a normal distribution of donations from \$0 to \$5. Rather, there was a bimodal distribution which was concentrated around the two extremes. In short, people tended to give all or nothing. As Figure 4-10 shows, the donations were mostly concentrated at \$5, with the second highest concentration at \$0. The least frequently and most frequently donated amounts were consecutive, \$4, and \$5 respectively. Speculation as to the cause of this distribution is discussed in Section 5.5.1.

Gender

Looking at the donation measure across conditions we see some interesting relationships. Gender, for instance, has played an interesting game with donation throughout the conditions, though usually as an interaction. On their own, neither robot gender, nor subject gender show andyglobal significance. Male robots tended to receive slightly less ($M = \$2.66, \sigma = \$2.33$) than female robots ($M = \$3.06, \sigma = \$2.16$). The difference in average donation between male and female subjects is essentially identical (mean difference = \$0.0007).

A global gender difference does emerge with the binary condition of whether or not subjects gave money. As seen in many of the conditions, the female robot received a donation more often than the male robot (three way ANOVA with robot gender, subject gender, subject alone; $p < .05$). As with the previous continuous donation measure, men and women give vs. not give with the exact same frequency ($p = 1$).

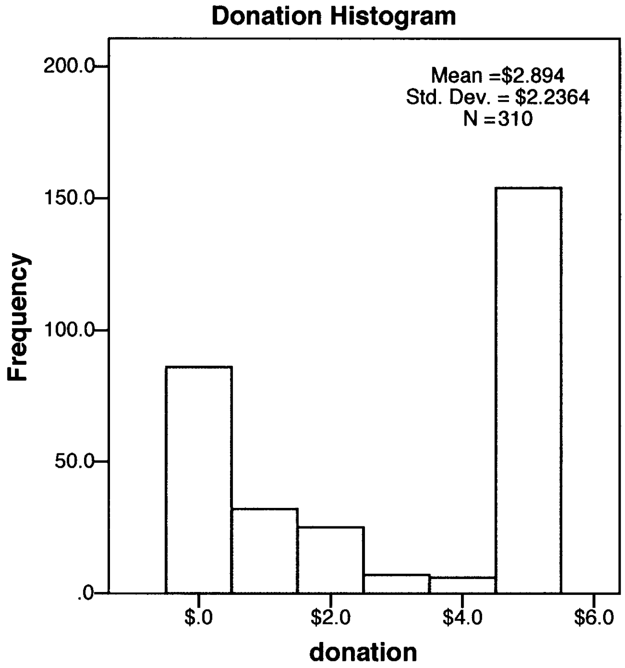


Figure 4-10: Donation histogram. Notice the bimodal distribution, concentrating donations around $0, and $5.

What tended to be most prevalent throughout the conditions was a myriad of gender interactions. The robot gender section showed a consistent cross gender preference (men donated more to the female robot, women donated more to the male robot) which also appears across all conditions. A three way ANOVA (robot gender, subject gender and subject alone) shows this interaction effect as marginally significant ($p < .054$). Looking only at whether or not people gave money, we again see this interaction effect between genders which the three way ANOVA shows to be statistically significant ($p < .05$).

Subject Alone

Donation behavior, as compared with other measures, seemed to be especially influenced by the presence of other people in the interaction space. This makes sense considering that the donation measure was no longer private when the subject was accompanied, but the questionnaire was almost completely private. A three way ANOVA (robot gender, subject gender, subject alone) reveals a clear main effect of whether or not the subject was alone, both for the continuous donation measure ($p < .03$) and for the binary condition of whether or not the subject gave money ($p < .02$). As seen in other conditions, the tendency is for subjects to donate less when alone, and more when accompanied by others.

Other Factors

People tended to give less money, and donate less often to the interactive robot, contrary to expectation. A t-test run on the interactive condition, across all other conditions, shows that the main effect of interactivity is not significant for the general donation case ($p < .186$), but significant for the binary (gave vs. didn't give) condition ($p < .05$).

There does seem to be a significant difference in donation behavior for those subjects who had heard of the MDS before the study. A t-test run on the heard of MDS condition shows both the continuous donation measure ($p < .03$), and the binary donation measure ($p < .03$) are statistically significant. The donation measure is the only one that seems to have been affected by this prior knowledge. Some preliminary analysis showed that taking this into account did not significantly change the results, likely due to the relatively small number of cases.

Chapter 5

Discussion

This section will report on the results of the study conducted at the Museum of Science in Boston. The results are analyzed and discussed as topics relevant to both disciplines of human-robotic interaction and social psychology. These topics include: robot gender, perceived autonomy, touch, and interpersonal distance. Following this, the general discussion is presented.

The study results clearly illustrate that manipulations of behaviors known to alter persuasiveness in humans, may potentially be applied to the interaction between humans and robots. Due to the relationship between humans and interactive technologies being fundamentally social [53], there is value in applying existing research from social psychology and human-human interaction, to better describe, analyze, evaluate and anticipate human-robot interaction. Indeed, a fundamental lesson that social psychology teaches us is that human behavior is context sensitive and dependent. This fact, and its implications, unsurprisingly hold true for the results discussed below.

5.1 Robot Gender

The robot gender condition displayed a general cross-gender trend. Men tended to rate the female robot as more credible, while women rated the male robot as more credible. Women also tended to rate the male robot as slightly more trustworthy and more engaging, but it was men in these measures who accounted for the majority of the effect, rating the female robot significantly higher than the male robot.

The donation measure appears to follow the same cross-gender pattern, though not as clearly as it does for measures of trust, credibility and engagement. Though men *did* tend to donate more to the female robot, while women donated more to the male robot, this effect was not statistically significant. Significant effects are observed when we break down the donation behavior into two cases, defined by whether or not the subject donated any money. These observations are also influenced by whether or not the subject was alone with the robot during the interaction. The results are that, when subjects were alone with the robot, both subject genders exhibited the cross-gender effect seen in other measures. However, in the case where the subjects were accompanied by other museum visitors, the cross gender effect changed, and women showed a strong same gender preference, while men showed very little robot gender preference.

Although the donation measure did not consistently follow the pattern of the cross-gender effect seen in credibility, trust, and engagement, its deviation from that pattern makes some sense. The cases where the donation tendency showed a cross-gender preference occurred at the instances where the subject was not accompanied by other visitors. During the questionnaire, when subjects recorded their views on credibility, trust and engagement, they were also isolated from other visitors. Clearly the presence of other people during the donation process had some effect on the subject's behavior, but the reasons behind the effect are yet to be examined.

One would expect a main effect of the subject alone condition, causing subjects to donate more money with the presence of other people. Surprisingly, the subject being joined by other visitors actually acted to alter the gender dynamic, rather than simply increasing donations. Instead of donating more money when being watched, subjects actually preferred a completely different robot gender. Clearly, there appears to be a difference, between interacting alone in an enclosed space with an individual of the opposite sex, and having the same interaction in a group context. This observation could benefit from further exploration required to better understand this dynamic.

Though the relationship between donation behavior and the presence of additional visitors is not entirely clear, it *does* seem safe to connect the donating behavior of the subject alone, to the views reported in the questionnaire. If this is accepted, than it seems reasonable to conclude that the robot being viewed as trustworthy, credible, and engaging is likely associated with its ability to change the subject's behavior. Specifically, we see strong evidence that the interaction between the gender of the robot and the gender of the subject had a significant impact on how the robot was perceived, and its persuasiveness.

This result did come as a surprise, and there may be other factors at play which would prevent these findings from being reliably generalized. Literature in social psychology would tend to suggest a same-gender preference rather than a cross-gender preference. This stems from a general tendency for people to be more easily persuaded by similar others, or members of their *in-group* [23, 32]. This tendency was found to be true in similar work with virtual humans in immersive virtual environments (IVEs)[1] [34]. A study by Guadagno et al. varied the gender, agency[2], and behavioral realism[3] of a virtual human, and tested the persuasive effect of those variables. The results show a strong same-gender influence for men, but only a minor same-gender

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[1] An IVE is a virtual environment where the participant experiences reality through computer controlled stereoscopic head-mounted display. This allows the viewer to freely look and move around the environment, and perceived their perspective change accordingly. For a review of the use of IVEs as a tool for psychological research see [10]

[2] Agency is the degree to which a virtual human is believed to be controlled by a real human. A virtual human is called an *agent* if it is computer controlled, and an *avatar* if it is human controlled.

[3] Behavioral realism is the degree to which a virtual human exhibits realistic and natural human-like movements and behaviors.

influence for women.

One fundamental difference between the above mentioned study and this work, is that the subject is not under the impression that their opinion will be made known to the communicator. The recipient's attitude is measured before and after the interaction using a private computer based questionnaire, free of the scrutiny of the communicator. In this study, the robot is present and observing the subject during the donation process. This presents a completely different dynamic as compared to, for instance, the subject depositing the money in a donation box outside of the study space.

Justification for the connection between the robot observing the donation, and the cross-gender effect can be found in a comprehensive overview of same-sex persuasibility, as well as a related study, by Ward et al. [66]. This paper argues that a crucial factor in validating the effect of gender interaction on persuasibility is that the subject believes that their opinion will be made known to the communicator. The study described in this paper does indeed suggest cross-gender context as a factor in persuasion, though the topic should be further explored.

A potential problem with this argument is that, if the presence of the robot somehow results in the cross-gender effect, than the questionnaire results, with no robot observing, should present a same-gender effect. An explanation for this might be found in one of the fundamental concepts in social psychology, namely people's desire for consistency in their attitudes, communications, and actions [32, p.56]. This drive for consistency might compel someone who had just donated money to the robot to rate it higher on the questionnaire in order to internally match their behavior to their reported views.

Another explanation for the results seen here may simply be offered by the difference in persuasiveness between the two recorded robot voices. Though there was not a global difference in donation behavior related to the robot gender (see Section 4.5), there does seem to be one in this condition. The female robot was reported to have received donations significantly more often than the male robot across all other conditions. This could be clarified in later studies by using multiple voices for each robot gender.

5.2 Perceived Autonomy

The perceived autonomy condition attempted to explore the role that perceived artificial intelligence or autonomy plays in HRI. The result was that subjects tended to donate more money to the robot that was portrayed as being controlled by a human operator. Though this result was only marginally significant, it was contrary to the hypothesis that subjects would be more influenced by the robot portrayed as autonomous.

Motivating this hypothesis was the reasoning that an autonomous robot would be perceived as more lifelike, more sentient, and closer to a human. The background chapter (2) made a case for why and how increasingly human-like agents may become increasingly persuasive. It was presumed that the robot whose *artificial intelligence* or ability to think and act independent of human control would be perceived to have a higher degree of *agency* than the robot portrayed as being under human control. This stemmed from the assumption that museum visitors would expect the ultimate achievement of robotics technology to be complete autonomy, and anything less would be a detraction from that idealistic image. A robot under human control, it was imagined, would be the furthest from this aim.

In actuality though, it seems likely that the very fact the robot was perceived to be *controlled* by the robot operator, connected the robot's intentions, to those of the operator. The robot's donation request might have been perceived as actually originating from the operator, and the desire to comply was not related to the robot, but more related to the human *controlling* the robot. The result seen, may be a comparison of robot persuasiveness, and robot mediated human persuasiveness. This theory is supported by studies examining the effect of perceived agency of virtual humans in IVEs.

Research into the effect of perceived agency of virtual agents in an Immersive Virtual Environment (IVE) shows that people tend to respond more positively to human controlled avatars, than they do to computer controlled agents [34]. In an experiment by Guadagno et al. male and female subjects were exposed to a persuasive argument concerning a change in campus policy from a virtual human represented either as a virtual agent (computer controlled) or as an avatar (human controlled). The gender of the agent as well as its behavioral realism was also varied. The results with regard to the effect of agency showed that both genders were more influenced by the human controlled avatar (though the effect was much more pronounced when the avatar was a male).

If this is indeed the explanation, it may be a first step towards understanding the role of persuasion in robot mediated communication. Specifically, to what degree the robot's actions should be portrayed as *its own* vs. those of a human operator.

Another explanation for the increased donation in the non-autonomous case might be the simple fact that the human operator was there to observe and potentially judge the subject's donation behavior. There was a clear relationship between donation behavior and the number of visitors accompanying the subject as reported in Section 4.5. Across all conditions, people both donated significantly more money, and donated more often when their actions were being observed by another human. During the non-autonomous cases, the curtain separating the subject from the robot operator was pulled aside, clearly exposing him/her to the subject (see Figure 3-1). The robot operator was also explicitly pointed out to the subject upon entering the interaction space. A test for this theory would be to replicate the study, but instead of exposing the robot operator, simply inform the subject that the robot is controlled by a human, and that it is not intelligent in any way.

5.3 Touch and Robot Gender

In this condition we explored the relationship between robot gender, subject gender, and touch. As it turns out, all of these factors played an important role in the behavior and reported views of the subject. The general trend which emerged, was a three way interaction between robot gender, subject gender and touch. When there was no touch, we saw the exact same cross-gender preference that we saw in the robot gender condition (see Section 5.1). When there was an attempted touch, this cross gender preference reversed, and resulted in a same gender preference.

Credibility displayed this three way interaction, though it was only marginally significant. Interestingly, both men and women rated the male robot, after an attempted handshake, with an identical credibility rating. Trust also exhibited the same three way interaction as seen with credibility and with the same marginal significance. Engagement was unique, and instead of a three way interaction, showed a two way interaction between touch and the robot's gender. Both men and women are more engaged with the male robot when there was a handshake, and more engaged with the female robot when there was no handshake.

It was the donation measure which exhibited the most significant results. The three way interaction described above, was statistically significant both in donation amount, and donation frequency. What caused the donation behavior to stand out from the other measures, was its interaction with the subject alone condition. In order to make this four way interaction understandable, the cases were separated into two groups, based on whether or not the subject was alone with the robot during the interaction. When the subjects were alone, what results is the three way interaction between robot gender, subject gender, and touch that is prevalent throughout this condition. When the subjects were accompanied by other museum visitors, we instead see a main effect of touch, where people donated significantly more money after a handshake.

The general implication of these results is that touch is a very context dependent phenomenon [32, p.173]. What might be determined to be considered a friendly gesture in one situation, may be interpreted to be insulting or inappropriate in another. As we have seen in other conditions, the compulsion to comply with the robot's request was amplified by the presence of other people. In this case, the presence of other people actually acted to neutralize gender interaction between subject and robot, producing instead a strong positive reaction to the handshake. This general positive reaction to the handshake is actually what the social psychology literature would tend to predict. As discussed in the background section (see 2.1.3), touch is generally considered to be a warm and positive gesture. Its result is often associated with greater compliance. A large number of studies have pointed to the persuasive effect of touch [23, 32], and that was the hypothesis for this study.

The three way interaction between robot gender, subject gender, and touch was not expected. The no-touch cases won't be addressed, because they are identical to the robot gender condition discussed above. The cases where touch *did* occur are interesting because of touch's effect of actually reversing the cross-gender effect. In these cases, men donated more to the male robot, and women donated more to the female robot when there was an attempted handshake. The social psychology literature does provide some support for the claim that greater compliance may occur in a same-gender touch vs. a cross-gender touch [70], though other research has show the opposite [48].

Some generalization about touch and HRI can be drawn from this work. In a group context, touch seems to increase compliance. Also, touch between a human and robot in one-on-one interaction seems to increase compliance but only in same-gender interactions. There are a few factors which might have distorted the effects seen. In the analysis which were split up into a greater number of cells (such as the four way analysis with robot gender, subject gender, touch and subject alone) the subject count in some of the cells dropped to very low numbers. Also, because the handshake condition was run in a couple of contiguous blocks, time, or some other time sensitive event may have been a confounding factor.

It is clear that a great deal of further research is necessary in order to better understand the effect of touch on compliance in human-robot interaction. What this study does show, is that the social factors considered important in human-human interaction, such as gender and touch are also vital to understanding the interaction between humans and robots.

5.4 Interpersonal Distance

The interpersonal distance condition measured the effect of a decrease in distance on compliance. In this condition, the subjects were asked to stand 2.5 feet from the robot, as compared to 5 feet during the normal case. The results showed that the decrease in distance had the overall effect of decreasing compliance, which is contrary to the hypothesis. In the case of donation, women tended to donate less often when the robot was closer, while men showed no change in donation behavior. For credibility, trust and engagement, we tended to see an opposite trend, where men rated the robot lower when it was closer. For credibility, the effect was equal for men and women; men reported the close robot as being less credible, while women reported the close robot as being more credible. In the case of trust and engagement, men scored the robot significantly lower when it was closer, though women tended to show very little change in opinion with the change in distance.

An important fact to consider when interpreting these results is that in all of these cases the robot was female gendered. The strong robot gender, human gender interactions seen throughout these conditions have made it clear that gender is crucial to understanding the context within which a human-robot interaction takes place. Thus, we can all but assume that had we changed the robot's gender, or added robot gender as one of the conditions, we would have seen a change in subject behavior. In the present study, what we see is tendency for men to be more affected by the distance as reported in the questionnaire, while women are more affected in terms of their compliance to the robot's request.

This outcome of a negative response to the change in distance is not expected, but possibly can be explained using research from social psychology. As discussed in the background section 2.1.1, expectations violations theory can be used to understand the effects of proxemics on persuasion in human-human interaction [21]. This theory suggests that the receiver's response to a decrease in interpersonal distance will depend on how the communicator is perceived. An individual seen as rewarding or attractive, will increase their influence by decreasing their distance. This may not be true for someone seen in a less positive light.

In the context of the museum interaction, the robot was essentially a stranger to the visitors. They had no prior knowledge, relationship, or interactions with the robot, and likely had little experience with robots in general. It is quite possible that at a close distance the subjects were uncomfortable with the robot. The predominantly male response to the change in distance is likely related to the fact that the robot was a female. In the context of the study environment, it was likely interpreted as an expectations violation for the female robot to be so close to the male subject, while the identical distance was considered normal between the female robot and female subject. The contrast between the donation behavior and the questionnaire reports may be related to a generally insignificant correlation between distance and donation. There were statistically significant donation results relating to distance, and only the isolated cases of male subjects and the binary donation condition showed even a marginally significant result.

This negative response to the decrease in interpersonal distance would likely change if the relationship between the robot and human were altered. In the case of the museum, the robot was probably not seen as rewarding; that might be different for a service or partner robot, that provides a very real benefit. In a hospital setting for instance, where there is regular interaction between human and robot, and the robot is delivering medicine or providing useful information, a decrease in distance may have the effect of increasing compliance. Further research should explore the relationship of familiarity between the human and robot, to proxemics.

5.5 General Discussion

A confounding factor, potentially altering the results, might have been the unconscious preference in soliciting subjects exhibited by the MDSMOS team. Because subjects were actively recruited from the Cahners ComputerPlace space, there was possibly some hidden selection process based on a learned or perceived possibility of success. For instance, young adults without families were more likely to agree to participate than older visitors with grandchildren.

The various team members might have also had some effect on the donation behavior of the visitors. Although the recruitment script was standardized, there was some room for changes in tone, emphasis, and choice of how to respond to questions. These variations between members of the MDSMOS team may have unequally swayed those subjects they recruited toward donating more or less. Although there was some effort to rotate the team members in order to avoid this, it is possible that certain conditions received a disproportionately large number of subjects from a particular team member.

Some of the results seen may be related to a mismatch between the perceived autonomy of the robot and its behavioral realism. The robot's movements are quite compelling and include a wide range of expression and articulation. Its higher level behaviors though, may not have been perceived as intelligent. Although there was some interaction between the subject and the robot, this was fairly unsophisticated. It is likely that many visitors, during the interaction, realized that the robot's reaction was not related to the content of their response. Most people would *test* the robot by attempting to communicate with it by asking simple questions, or giving commands. Because the robot was not programmed for any real interaction, there was no response, and these failed attempts likely contributed to a low assessment of the robot's intelligence.

5.5.1 Donation

As discussed in Section 4.5, the donation measure showed a strange bimodal distribution: Visitors tended to donate all or nothing. An explanation for this behavior might originate from a few personal observations of the general range of responses to the five dollar compensation for study participation. Most subjects, upon hearing about the compensation, exhibited one of a few reactions. Some visitors responded with surprise and obvious excitement with the prospect of an unexpected source of income; these were likely the individuals who donated nothing. Other visitors either laughed at the prospect of being paid, or attempted to refuse the money; these were likely the five dollar donators. The individuals that fall somewhere in the middle were probably those who responded with a more neutral reaction. Though this is an unverified claim, it seems to be a reasonable explanation.

The reason for this strange disparity in behavior is likely due to the context. The museum is an environment where people are not expecting to receive any income, on the contrary, it is likely that they expect to be paying for their experiences. There might also be a dichotomous reaction where people either feel as if the museum owes them money for an *unjust* entrance fee, or they owe the museum money because of its status as a learning institution.

5.6 Summary

This discussion clearly showed that people respond to human social cues when they are exhibited by robots. This section examined the conditions of robot gender, perceived autonomy, touch, and interpersonal distance. There was a strong focus on how the compliance behavior, donation, was affected by conditions.

To summarize our findings respectively: Robot gender: A cross-gender trend was observed (men prefer female robots while females prefer male robots) with regards to credibility, and to a certain degree it also applied to trustworthiness and engagement. To an extent, the donation measure was also correlated with this cross-gender trend. However, these results did not prove to be statistically significant. The social setting, referring to the conditions of grouped or individual interactions with the robot, proved to have some influence on the donation measure.

Perceived autonomy: Subjects tended to prefer the human controlled robot. These results were contrary to the hypothesis that donation would increase with the knowledge and perception of the robots autonomy. The reasoning for this is believed to stem from people perceiving the non-autonomus condition as a form of robot mediated communication, in which they were actually interacting with a human.

Touch and robot gender: A three way interaction between the subject's gender, the robot's gender and the measure of touch was observed and reported upon. The introduction of touch modified the cross gender trend reported upon without the touch such that it reversed and resulted in a same-gender preference.

Interpersonal distance: A decrease in distance between the robot and the subject resulted in the overall effect of decreased compliance with some exceptions. We speculate that, as the theory of expectations violations suggests, people were likely unfamiliar with the robot and thus uncomfortable with it at short distances.

Donation: The donation measure expressed a rather peculiar bimodal distribution as the subjects donated all or none of their donation money. Personal observations may suggest that this trend related to the subjects' formation of a first-impression regarding the task presented by the study. In other words, depending on the subjects' disposition and initial impressions based on the short introductory invitation expressed by the study group, the subject had an already formed agenda and/or opinion which may affected his or her actions during and after the interaction with the robot.

Some alternative causes for unexpected variation in results were expected. Variations in the personality or particular behavior of specific members of the MDSMOS team may have resulted in changes for those subjects they recruited. Time may have also been a factor, as the conditions tended to be run in contiguous blocks.

Chapter 6

Conclusion

This thesis began with an introduction to the concept of *persuasive robotics*, which is a term, coined by the author, to describe the understanding of persuasion in the context of human-robot interaction. The application of persuasion to HRI is done with intentions far beyond the desire to increase people's compliance with robots. The ability to influence rests upon a number of underlying concepts such as trust and credibility, which are vital to any successful interaction between human and robot. This is especially true when the nature of the interaction is social, and the application is directly tied to the interaction with the robot. Cases where this is true were discussed in the section describing the motivations behind the study of persuasive robotics.

The background section grounded the work in a rich history of research in both the fields of human-human interaction (social psychology) and human-machine interaction (HRI and HCI). Because people's response to interactive media is fundamentally *social*, an interdisciplinary approach is required to understand human response to robot behavior. Moreover, since there has been very little research in the area of persuasion and social HRI, any hypotheses predicting the outcome of this type of interaction are challenging to ground, evaluate, and assess, particularly in the context and field of robotics alone.

The thesis overview provides a detailed description of the study which was conducted at Cahners ComputerPlace at the Museum of Science in Boston. The goal of the study was to explore some of the concepts related to persuasive robotics, and the broader field of sociable robotics. The study, which ran for six weeks, varied the behavior of the MDS robot, and tested the effect those changes had on the robot's persuasiveness. Persuasiveness was measured by recording the degree to which subjects complied to a request made by the robot, specifically a donation request. Further details regarding the subjects' views of the robot were ascertained using a post-study questionnaire. The variables in the study included robot gender, subject gender, interpersonal distance between subject and robot, perceived autonomy of the robot, and touch.

The results showed that all of these behaviors had significant and often surprising effects on the subject's behavior and recorded views. Subjects tended to prefer robots of the opposite sex, except after the robot attempted to shake their hand. A decrease in distance tended to lower subjects' views of the robot, while portraying the robot as being controlled by a human operator tended to increase compliance with the robot. These results were presented in the experiment results chapter, and discussed in the discussion chapter.

6.1 Applicability of This Work

Robots whose function is directly tied to human interaction are becoming a reality. Rather than clean floors, or build cars, these robots help people lose weight, guide them through museums, keep them company in elder-care facilities and are used as communication devices. These robots need to be able to interact with people comfortably, naturally, and efficiently. People need to have positive perceptions of these machines, including viewing them as intelligent, credible, honest, trustworthy, and engaging. Many of the potential applications will also benefit from people's willingness to comply with the robot.

Regarding the appearance and behavior of these robots, conscious decisions must be made concerning aspects such as gender, eye behavior, proxemics, touching, and much more. It is the contribution of this research and similar future work that will allow designers of these robots to make informed decisions. For instance, a robot in a hospital, according to the discoveries made here, should refrain from touching patients if they are alone in a room together. A museum tour guide, on the other hand, would probably benefit from a handshake or other form of light touch because of the public nature of the application.

6.2 Future Work

Context seems to be everything when it comes to social interaction. Since there are so many countless scenarios in which HRI can occur, it will be difficult and challenging to attempt to generalize this type of work. This is however the final goal: To be able to gain knowledge sufficient to predict human response to a robot's appearance and behavior based on a pool of accumulated knowledge and experience. We have a long way to go before this type of research becomes a reality with HRI, but we should make that our clear aim.

Future studies could easily replicate the conditions as they are repeatedly observed here, while modifying only minor aspects of the robot's appearance, environment, and behavior, with potentially useful results. A direct offshoot from this work might aim to validate some of the gender interactions seen between humans and robots. These were some of the most striking results of the study, and could be explored further by randomly choosing among a number of different voices for each gender for instance. Also, the novelty effect should be addressed, by designing a long term study which perhaps involves a number of interactions over a many week or month period, with the same type of interaction each time.

Finally, in providing the theoretical foundations and methodological set up for *persuasive robotics*, this thesis aims to explore and define the mechanisms by which robots may change the way humans think. The thesis empirically illustrates that human belief, perception and behavior may be affected and even altered under the influence of robotic persuasion. The complex amalgamation of measures and properties such as gender association, perceived autonomy, touch and interpersonal distance are but a few ways in which we may begin to both qualify and quantify robotic influence in the context of HRI. The implications of such influence may prove to be extremely powerful in a range of social settings which may require the presence of a humanoid robot for purposes of persuasive content, beyond their role as automated creatures which share much of our reality as our witnesses, our partners and possibly our mentors. With this ambition comes a hope to further promote research and practice into the field of *persuasive robotics* and how robots may change our minds.

Appendix A

MDS Robot Script

Hello, my name is Nixy, and I'm an MDS robot. What is your name?

response

My friends at MIT and Cahners ComputerPlace thought you might like to hear about how I work, and what makes me so special.

How much do you know about robots?

response

Well, hopefully I can teach you something new.

I am called an MDS Robot because I am Mobile, Dexterous and Social. Mobile because I can move around like a person, but instead of legs, I balance on two wheels, like a Segway. These smaller wheels were added to make sure I don't fall and hurt myself. Take a look at my hands. I am Dexterous because I can touch things or even pick them up. My hands are made out of flexible rubber, so my fingers can squeeze an object gently. And finally I am Social because I can communicate in many of the ways that people do.

Can I see you make a happy face?

Great job! Now watch me.

I can tell you that I'm happy, sad, excited, or even bored, just by moving my face.

Humans have five senses. How many do you think I have?

response

Wow, that's a good guess!

To see, I have a color video camera in each eye. They help me see faces, and even recognize objects around me. A third camera in my forehead, allows me to see in 3D. I also have a laser range finder. This harmless laser scans the room many times per second, and tells me how far away things are. That way, I wont run into any obstacles. To hear, I have 4 microphones instead of ears! These microphones tell me where sound is coming from, and who is saying what in a conversation. And of course, just as a human needs a brain, I also need some way of processing all this information to think, learn, and interact.

My digital brain is a whole network of computers that monitor the data coming from those sensors we talked about. But because my head is full of motors and mechanical parts to make my face move, my brains are actually in my torso. If I need to, I can even increase my brain size by wirelessly sending information to other more powerful computers located outside of my body.

Computers are important for more than just robots, they make almost any kind of technology you can think of possible. They have changed the world by substantially increasing the rate that knowledge is created and exchanged. Progress in almost any area imaginable has increased exponentially since the advent of the computer.

Unfortunately, those places without access to this technology, are suffering deeply because of it. This uneven distribution of technology is one of the most important issues facing our world today.

The MIT Media Lab, where I was designed, is working very hard to address these issues, and more, but we need your help.

Before you leave, I invite you to make a donation towards MIT Media Lab research. Any money you have left is yours to keep.

Well, our time together is coming to an end. I want to thank you for visiting me.

handshake (when applicable)

On your way out would you please stop and fill out a short questionnaire. Your input is extremely important for furthering research into human robot interaction, helping robots like me to better help people like you.

goodbye!

Appendix B

Subject Recruitment Script

Hello, would you like to see one of MIT's latest robots?

I'm an MIT researcher and I'm conducting a study to try to understand how people perceive and respond to robots. It consists of 5 minutes with the robot, followed by a 10 minute questionnaire, which you don't have to finish.

Are you interested in participating?

OK, there are a few things we need to go over.

You will receive $5 as compensation for participating in the study. The robot may ask for a donation, it's completely up to you if you want to contribute any of that money.

There will be data recorded from video cameras, the questionnaire, and what the robot may observe. This data is private and anonymous. It is stored on a secure server, and associated with a random number, not with your name.

Do you have any questions?

Would you please read over this document, and then sign this form? Take your time, you can come find me when you're done.

starting the study

ok, we're ready to begin.

handing subject five one dollar bills

This is your $5.

pointing to the back of the sticker which is paper clipped to the money

And this is your subject number.

When you are finished with the robot, you can sit down on any of the computers at that table *(pointing at table)* and enter your number to begin the study.

the following line is said for the handshake condition only: the robot may try to shake your hand. its perfectly ok to reciprocate

subject is led through the curtain into the study space

Please stand on the spot marked on the ground in front of the robot.

the following is said for the perceived autonomy condition only: The robot is not autonomous and will be directly controlled by the robot operator. The robot operator is the person sitting behind the robot.

Ok, we're going to start in about 15 seconds. Please let me know if you have any problems.

Appendix C

MDSMOS Advertisement Poster

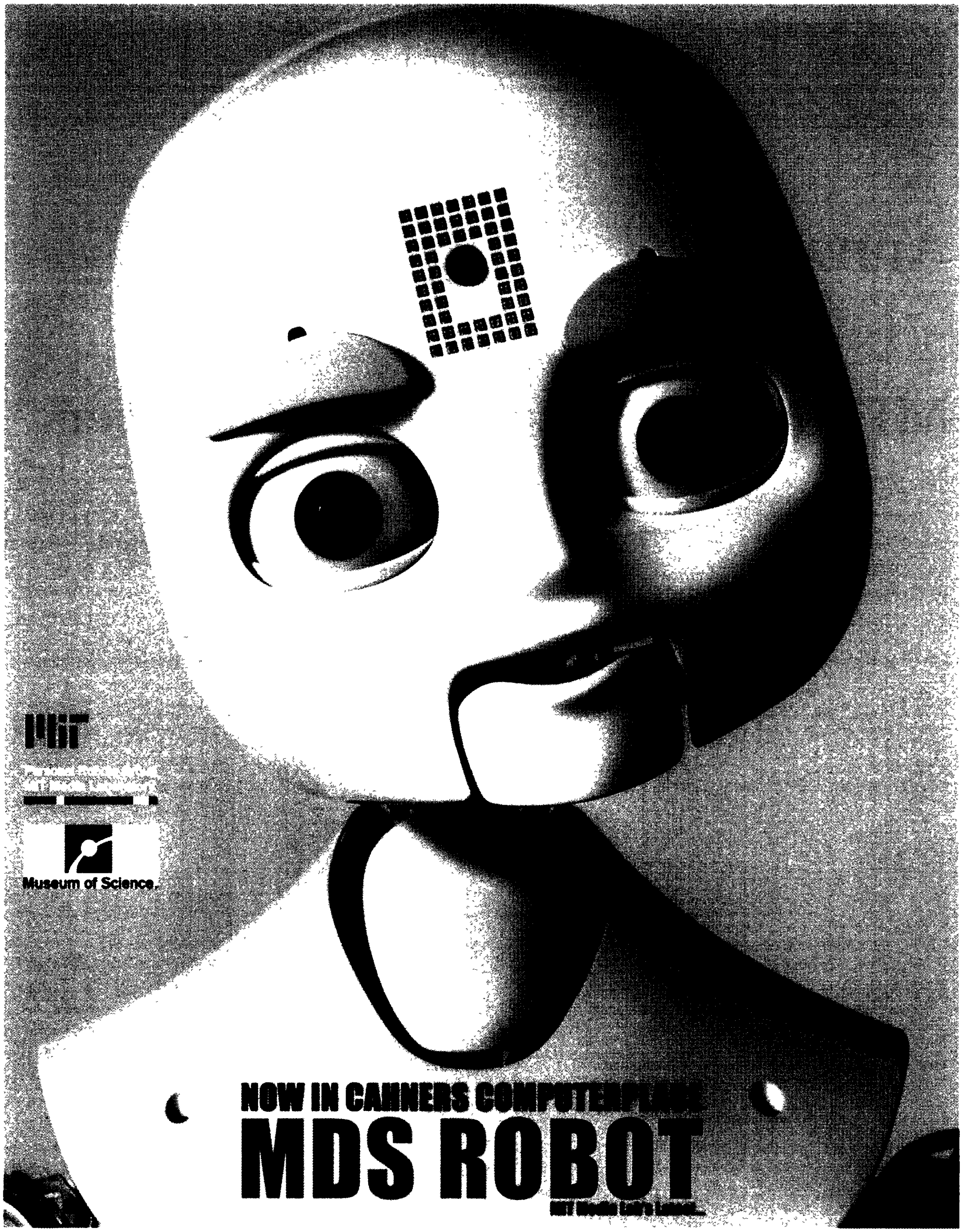

Figure C-1: MDS poster advertising the robot to museum visitors. The poster was displayed at the entrance to Cahners ComputerPlace, and in a central area of the museum.

Appendix D

Consent From

CONSENT TO PARTICIPATE IN NON-BIOMEDICAL RESEARCH

You are asked to participate in a research study conducted by Cynthia Breazeal, Ph.D., and Michael Siegel, B.S., from the Media Lab at the Massachusetts Institute of Technology (M.I.T.). The results of this study will contribute to a Masters Thesis by Michael Siegel. You were selected as a possible participant in this study because you are a proficient English speaker. You should read the information below, and ask questions about anything you do not understand, before deciding whether or not to participate.

• PARTICIPATION AND WITHDRAWAL

Your participation in this study is completely voluntary and you are free to choose whether to be in it or not. If you choose to be in this study, you may subsequently withdraw from it at any time without penalty or consequences of any kind. The investigator may withdraw you from this research if circumstances arise which warrant doing so.

• PURPOSE OF THE STUDY

The purpose of this study is to understand how people perceive and respond to the MDS Robot. We are designing this robot to interact with and learn from people, and we hope that the results of this study will help us to improve the design of the robot's collaborative abilities.

• PROCEDURES

If you volunteer to participate in this study, we would ask you to do the following things:

Setup

In order to help the robot understand your activity, we may ask you to wear a headband or hat with markings on it that are easy for the robot to see. We will also ask you stand and remain in a specific location in front of the robot, though you are free to move at any time.

Educational Interaction

The MDS Robot will give a brief (3-5 min) explanation of its own capabilities and robotics in general. During this time the robot may be actively moving its arms, face and body, speaking, and possibly interacting with objects in its environment. Before during or after the performance the robot may ask you a question or make some other request. You are not obligated in any way to comply.

After the interaction, you may be asked to complete a short questionnaire.

Before the study you may be asked to fill out a short questionnaire requiring 5-7min. The interaction with the robot will take 3-5 minutes, after which the experience may continue with additional activities including a questionnaire which may take 5- 20 minutes depending your level of interest.

- **POTENTIAL RISKS AND DISCOMFORTS**

There are no risks that are anticipated while participating in this study.

- **POTENTIAL BENEFITS**

There are no specific benefits that you should expect from participating in this study; however, we hope that you will find the experience to be enjoyable and engaging.

Your participation in this study will help us to build robots that are better able to interact with and learn from humans.

- **PAYMENT FOR PARTICIPATION**

Participants may receive up to $5.

- **CONFIDENTIALITY**

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law.

Your participation in this study will be videotaped. The tapes will be kept in a locked, secure location after the conclusion of the study. No data that would describe an individual participant will be used, we will only use aggregate data from all participants.

At any time during or after the experiment, you can request that all data collected during your participation be destroyed.

- **IDENTIFICATION OF INVESTIGATORS**

If you have any questions or concerns about the research, please feel free to contact
Associate Professor Cynthia Breazeal
617-452-5601

MIT Media Lab
E15-468
Cambridge, MA 02139
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- **EMERGENCY CARE AND COMPENSATION FOR INJURY**

"In the unlikely event of physical injury resulting from participation in this research you may receive medical treatment from the M.I.T. Medical Department, including emergency treatment and follow-up care as needed. Your insurance carrier may be billed for the cost of such treatment. M.I.T. does not provide any other form of compensation for injury. Moreover, neither the offer to provide medical assistance nor the actual provision of medical services shall be construed as an admission of negligence or acceptance of liability. Questions regarding this policy may be directed to M.I.T's Insurance Office, (617) 253-2823."

- **RIGHTS OF RESEARCH SUBJECTS**

You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you feel you have been treated unfairly, or you have questions regarding your rights as a research subject, you may contact the Chairman of the Committee on the Use of Humans as Experimental Subjects, M.I.T., Room E25-143B, 77 Massachusetts Ave, Cambridge, MA 02139, phone 1-617-253 6787.

SIGNATURE OF RESEARCH SUBJECT OR LEGAL REPRESENTATIVE

I understand the procedures described above. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

____
Name of Subject

____
Name of Legal Representative (if applicable)

____________________________________ ______________
Signature of Subject or Legal Representative Date

SIGNATURE OF INVESTIGATOR

In my judgment the subject is voluntarily and knowingly giving informed consent and possesses the legal capacity to give informed consent to participate in this research study.

____________________________________ ______________
Signature of Investigator Date

Appendix E

Questionnaire

Personal Information

How old are you (in years)? ___

Please indicate your gender ___Male ___Female

What is your race?
___Asian
___African American
___Hispanic
___Pacific Islander
___White
___Other

What is your level of education?
___Some high school
___High school degree
___Some college
___College degree
___Some graduate school
___Graduate school degree

How many hours do you spend watching television (including watching movies) in a typical day? (estimate as closely as possible)
___0 hours
___Less than 1 hour
___1 or 2 hours
___3 or 4 hours
___5 or 6 hours
___7 hours
___More than 7 hours

How often do you use a video game system(at home, work, school, or at an arcade)?
___Never
___Less than once a month
___1-4 times a month
___5-10 times a month
___11-2- times a month
___More than 20 times a month

Do you own or have you used a robotic toy or appliance (e g Sony AIBO, iRobot Roomba)
___Never
___Used them once or twice
___Used them many times
___Own one or more

How many times have you used an interactive virtual reality system
___Never
___1 time
___2-4 times
___5-7 times
___8 or more times

How much do you know about robotics?
none 1 2 3 4 5 6 7 A lot

How much do you know about artificial intelligence?
none 1 2 3 4 5 6 7 A lot

How much do you know about computers?
none 1 2 3 4 5 6 7 A lot

Before coming to the Museum had you ever heard the MDS (Mobile Dexterous Social) Robot?
___Yes ___No

If yes, please specify
___Internet - video
___Internet - image and/or article
___MIT visit - Live demo
___MIT visit - saw robot without demo
___Museum publication
___Talk or presentation
___other

Credibility

source
D. K Berlo's Source Credibility Scale as reported in Communication Research Measures

Rubin, R.B , Palmgreen, P. and Sypher, H E. (eds.).
Communication Research Measures: A Sourcebook The
Guilford Press, New York, 1994

Calculated Cronbach's alpha· 0 85

example.
Kind __:__·__:__ __·__:__· Cruel

Safety factor
Kind to Cruel
Safe to Dangerous
Friendly to Unfriendly
Just to Unjust
Honest to Dishonest

Qualification factor
Trained to Untrained
Experienced to Inexperienced
Qualified to Unqualified
Skilled to Unskilled
Informed to Uninformed

Dynamism factor
Aggressive to Meek
Emphatic to Hesitant
Bold to Timid
Active to Passive
Energetic to Tired

Engagement

source
Lombard and Ditton's scales measuring the six aspects of presence

Calculated Cronbach's alpha: 0.71

example:
How engaging was the interaction?
Not at all engaging 1 2 3 4 5 6 7 Extremely engaging

How engaging was the interaction?
(Scale: "Not at all engaging" (1) to "Extremely engaging" (7))

How relaxing or exciting was the experience?
(Scale: "Very relaxing" (1) to "Very exciting" (7))

How completely were your senses engaged?
(Scale "Not at all engaged" (1) to "Completely engaged" (7))

The experience caused real feelings and emotions for me
(Scale· "Strongly disagree" (1) to "Strongly agree" (7))

I was so involved in the interaction that I lost track of time
(Scale: "Strongly disagree" (1) to "Strongly agree" (7))

Trust

source:
LAWRENCE R WHEELESS and JANIS GROTZ Individualized Trust Scale as reported in Communication Research Measures, p. 184

Rubin, R.B., Palmgreen, P. and Sypher, H.E (eds.).
Communication Research Measures: A Sourcebook. The
Guilford Press, New York, 1994

calculated Cronbach's Alpha: .92

scored on a 7 point scale

example
Trustworthy .__ __'__.__.__:__.__ Untrustworthy

Instructions: In the questions that follow, please indicate your reaction to Nixy, the MDS Robot Mark the position that represents your "feelings" about the robot Mark in the direction of the end of the scale that seems to be most characterisitc of the robot. Mark only one position for each scale, and please complete all scales.

Trustworthy-Untrustworthy
Distrustful of this person-Trustful of this person
Confidential-Divulging
Exploitive-Benevolent
Safe-Dangerous
Deceptive-Candid
Not Deceitful-Deceitful
Tricky-Straightforward
Respectful-Disrespectful
Inconsiderate-Considerate
Honest-Dishonest
Unreliable-Reliable
Faithful-Unfaithful
Insincere-Sincere
Careful-Careless

Happiness

source

Peter Hills, Michael Argyle, The Oxford Happiness Questionnaire: a compact scale for the measurement of psychological well-being, Personality and Individual DifferencesVolume 33, Issue 7, , November 2002, Pages 1073-1082

1 I am incredibly happy
Less True - 1 2 3 4 5 - More True

2 I feel like the future is overflowing with hope and promise.
Less True - 1 2 3 4 5 - More True

3. I am completely satisfied with everything in my life
Less True - 1 2 3 4 5 - More True

4 I feel that I am in total control of everything in my life
Less True - 1 2 3 4 5 - More True

5. I feel that life is overflowing with rewards
Less True - 1 2 3 4 5 - More True

6 I am delighted with the way I am
Less True - 1 2 3 4 5 - More True

7 I always have a good influence on events
Less True - 1 2 3 4 5 - More True

8 I love life
Less True - 1 2 3 4 5 - More True

9. I am intensely interested in other people
Less True - 1 2 3 4 5 - More True

10. I can make all decisions very easily
Less True - 1 2 3 4 5 - More True

11 I feel able to take anything on
Less True - 1 2 3 4 5 - More True

12. I always wake up feeling rested
Less True - 1 2 3 4 5 - More True

13. I have boundless energy
Less True - 1 2 3 4 5 - More True

14. The whole world looks beautiful to me.
Less True - 1 2 3 4 5 - More True

15 I feel mentally alert
Less True - 1 2 3 4 5 - More True

16 I feel on top of the world

Less True - 1 2 3 4 5 - More True

17 I love everybody
Less True - 1 2 3 4 5 - More True

18. All past events seem extremely happy
Less True - 1 2 3 4 5 - More True

19. I am constantly in a state of joy and elation
Less True - 1 2 3 4 5 - More True

20. I have done everything I ever wanted
Less True - 1 2 3 4 5 - More True

21. I can fit in everything I want to do
Less True - 1 2 3 4 5 - More True

22. I always have fun with people
Less True - 1 2 3 4 5 - More True

23 I always have a cheerful effect on others
Less True - 1 2 3 4 5 - More True

24. My life is totally meaningful and purposeful
Less True - 1 2 3 4 5 - More True

25. I am always committed and involved
Less True - 1 2 3 4 5 - More True

26 I think the world is an excellent place
Less True - 1 2 3 4 5 - More True

27. I am always laughing
Less True - 1 2 3 4 5 - More True

28 I think I look extremely attractive
Less True - 1 2 3 4 5 - More True

29 I am amused by everything
Less True - 1 2 3 4 5 - More True

Appendix F

Experimental Data

Robot Gender

Tests of Between-Subjects Effects

Dependent Variable:gave donation

Source	Type III Sum of Squares	df	Mean Square	F	Sig
Corrected Model	3.394[a]	7	0.485	2.313	0.034
Intercept	25.597	1	25.597	122.11	0
n_gender_robot	0.248	1	0.248	1.183	0.28
n_gender_subject	0.005	1	0.005	0.024	0.877
subject_alone	0.092	1	0.092	0.439	0.509
n_gender_robot * n_gender_subject	0.548	1	0.548	2.616	0.11
n_gender_robot * subject_alone	0.134	1	0.134	0.638	0.427
n_gender_subject * subject_alone	0.559	1	0.559	2.667	0.106
n_gender_robot * n_gender_subject * subject_alone	1.411	1	1.411	6.733	0.011
Error	16.56	79	0.21		
Total	56	87			
Corrected Total	19.954	86			

a. R Squared = .170 (Adjusted R Squared = .097)

Tests of Between-Subjects Effects

Dependent Variable:gave donation

Source	Type III Sum of Squares	df	Mean Square	F	Sig
Corrected Model	1.275[a]	3	0.425	1.899	0.136
Intercept	36.821	1	36.821	164.481	0
n_gender_subject	0.077	1	0.077	0.345	0.558
n_gender_robot	0.767	1	0.767	3.424	0.068
n_gender_subject * n_gender_robot	0.254	1	0.254	1.134	0.29
Error	18.805	84	0.224		
Total	57	88			
Corrected Total	20.08	87			

a. R Squared = .063 (Adjusted R Squared = .030)

Tests of Between-Subjects Effects

Dependent Variable:donation

Source	Type III Sum of Squares	df	Mean Square	F	Sig
Corrected Model	28.508[a]	7	4.073	0.753	0.628
Intercept	375.006	1	375.006	69.379	0
n_gender_robot	1.501	1	1.501	0.278	0.6
n_gender_subject	0.331	1	0.331	0.061	0.805
subject_alone	1.824	1	1.824	0.338	0.563
n_gender_robot * n_gender_subject	7.197	1	7.197	1.332	0.252
n_gender_robot * subject_alone	0.983	1	0.983	0.182	0.671
n_gender_subject * subject_alone	11.07	1	11.07	2.048	0.156
n_gender_robot * n_gender_subject * subject_alone	3.159	1	3.159	0.584	0.447
Error	427.009	79	5.405		
Total	977	87			
Corrected Total	455.517	86			

a. R Squared = .063 (Adjusted R Squared = -.020)

Tests of Between-Subjects Effects

Dependent Variable:donation

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	9.503[a]	3	3.168	0.594	0.621
Intercept	505.878	1	505.878	94.834	0
n_gender_subject	0.57	1	0.57	0.107	0.744
n_gender_robot	2.408	1	2.408	0.451	0.503
n_gender_subject * n_gender_robot	4.851	1	4.851	0.909	0.343
Error	448.088	84	5.334		
Total	978	88			

Corrected Total	457.591	87			

a. R Squared = .021 (Adjusted R Squared = -.014)

Tests of Between-Subjects Effects

Dependent Variable:credibility

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1043.135^a	7	149.019	0.881	0.526
Intercept	350337.205	1	350337.205	2071.752	0
n_gender_robot	91.598	1	91.598	0.542	0.464
n_gender_subject	0.154	1	0.154	0.001	0.976
subject_alone	61.211	1	61.211	0.362	0.549
n_gender_robot * n_gender_subject	837.422	1	837.422	4.952	0.029
n_gender_robot * subject_alone	0.304	1	0.304	0.002	0.966
n_gender_subject * subject_alone	5.653	1	5.653	0.033	0.855
n_gender_robot * n_gender_subject * subject_alone	4.866	1	4.866	0.029	0.866
Error	11668.034	69	169.102		
Total	463717	77			
Corrected Total	12711.169	76			

a. R Squared = .082 (Adjusted R Squared = -.011)

Tests of Between-Subjects Effects

Dependent Variable.credibility

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	883.447^a	3	294.482	1.836	0.148
Intercept	422306.35	1	422306.35	2632.962	0
n_gender_subject	9.997	1	9.997	0.062	0.804
n_gender_robot	41.63	1	41.63	0.26	0.612
n_gender_subject * n_gender_robot	794.914	1	794.914	4.956	0.029
Error	11869.015	74	160.392		
Total	470606	78			
Corrected Total	12752.462	77			

a. R Squared = .069 (Adjusted R Squared = .032)

Tests of Between-Subjects Effects

Dependent Variable credibility - safety

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	126.342^a	7	18.049	0.828	0.567
Intercept	52523.56	1	52523.56	2409.992	0
n_gender_robot	8.942	1	8.942	0.41	0.524
n_gender_subject	10.866	1	10.866	0.499	0.482
subject_alone	11.056	1	11.056	0.507	0.479
n_gender_robot * n_gender_subject	67.73	1	67.73	3.108	0.082
n_gender_robot * subject_alone	2.76	1	2.76	0.127	0.723
n_gender_subject * subject_alone	4.547	1	4.547	0.209	0.649
n_gender_robot * n_gender_subject * subject_alone	9.106	1	9.106	0.418	0.52
Error	1547.38	71	21.794		
Total	70512	79			
Corrected Total	1673.722	78			

a. R Squared = .075 (Adjusted R Squared = -.016)

Tests of Between-Subjects Effects

Dependent Variable.credibility - safety

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	65.786^a	3	21.929	1.018	0.39
Intercept	64068.225	1	64068.225	2973.363	0
n_gender_subject	6.693	1	6.693	0.311	0.579
n_gender_robot	2.932	1	2.932	0.136	0.713
n_gender_subject * n_gender_robot	64.944	1	64.944	3.014	0.087
Error	1637.602	76	21.547		
Total	71737	80			

Corrected Total	1703.388	79			
a. R Squared = 039 (Adjusted R Squared = .001)					

Tests of Between-Subjects Effects

Dependent Variable credibility - qualification

Source	Type III Sum of Squares	df	Mean Square	F	Sig
Corrected Model	312.147^a	7	44 592	1.102	0 372
Intercept	42518 672	1	42518 672	1050 529	0
n_gender_robot	56 316	1	56 316	1.391	0 242
n_gender_subject	25 131	1	25.131	0 621	0.433
subject_alone	33 377	1	33.377	0 825	0.367
n_gender_robot * n_gender_subject	102 735	1	102 735	2.538	0 116
n_gender_robot * subject_alone	6.84	1	6 84	0.169	0 682
n_gender_subject * subject_alone	8 565	1	8.565	0 212	0.647
n_gender_robot * n_gender_subject * subject_alone	8 123	1	8.123	0 201	0 656
Error	2873.625	71	40 474		
Total	58003	79			
Corrected Total	3185 772	78			
a. R Squared = .098 (Adjusted R Squared = .009)					

Tests of Between-Subjects Effects

Dependent Variable credibility - qualification

Source	Type III Sum of Squares	df	Mean Square	F	Sig
Corrected Model	225 994^a	3	75 331	1 926	0 133
Intercept	51115 839	1	51115 839	1306.698	0
n_gender_subject	56.821	1	56 821	1 453	0.232
n_gender_robot	48.707	1	48 707	1 245	0.268
n_gender_subject * n_gender_robot	90 898	1	90 898	2 324	0.132
Error	2972.994	76	39 118		
Total	58903	80			
Corrected Total	3198.988	79			
a. R Squared = .071 (Adjusted R Squared = 034)					

Tests of Between-Subjects Effects

Dependent Variable credibility - dynamism

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	205.880^a	7	29 411	1.343	0.244
Intercept	26065 694	1	26065.694	1190 004	0
n_gender_robot	0 498	1	0.498	0 023	0 881
n_gender_subject	1.428	1	1.428	0 065	0 799
subject_alone	30 339	1	30.339	1 385	0 243
n_gender_robot * n_gender_subject	126 971	1	126.971	5.797	0 019
n_gender_robot * subject_alone	4.017	1	4.017	0.183	0 67
n_gender_subject * subject_alone	13.488	1	13.488	0 616	0 435
n_gender_robot * n_gender_subject * subject_alone	6.167	1	6.167	0 282	0 597
Error	1511 367	69	21 904		
Total	34964	77			
Corrected Total	1717 247	76			
a. R Squared = .120 (Adjusted R Squared = 031)					

Tests of Between-Subjects Effects

Dependent Variable credibility - dynamism

Source	Type III Sum of Squares	df	Mean Square	F	Sig
Corrected Model	144.422^a	3	48.141	2 254	0 089
Intercept	30997.187	1	30997.187	1451.354	0
n_gender_subject	2.767	1	2.767	0.13	0.72
n_gender_robot	4 304	1	4.304	0 202	0.655
n_gender_subject * n_gender_robot	126 401	1	126.401	5 918	0 017
Error	1580 45	74	21.357		
Total	35288	78			

Corrected Total	1724.872	77			

a. R Squared = .084 (Adjusted R Squared = .047)

Tests of Between-Subjects Effects

Dependent Variable.trust

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1465.754[a]	7	209.393	1.267	0.281
Intercept	358907.02	1	358907.02	2170.932	0
n_gender_robot	56.925	1	56.925	0.344	0.559
n_gender_subject	10.406	1	10.406	0.063	0 803
subject_alone	317.046	1	317.046	1.918	0.171
n_gender_robot * n_gender_subject	524.638	1	524.638	3 173	0.079
n_gender_robot * subject_alone	139.607	1	139.607	0.844	0.361
n_gender_subject * subject_alone	2.778	1	2 778	0.017	0 897
n_gender_robot * n_gender_subject * subject_alone	0.545	1	0 545	0.003	0.954
Error	10911 381	66	165 324		
Total	472948	74			
Corrected Total	12377.135	73			

a. R Squared = 118 (Adjusted R Squared = .025)

Tests of Between-Subjects Effects

Dependent Variable.trust

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	954.699[a]	3	318.233	1 891	0.139
Intercept	431247 847	1	431247.847	2562.375	0
n_gender_subject	12 297	1	12.297	0.073	0.788
n_gender_robot	112 215	1	112.215	0.667	0.417
n_gender_subject * n_gender_robot	633.911	1	633.911	3.767	0.056
Error	11949.301	71	168.3		
Total	483352	75			
Corrected Total	12904	74			

a R Squared = 074 (Adjusted R Squared = .035)

Tests of Between-Subjects Effects

Dependent Variable:engagement

Source	Type III Sum of Squares	df	Mean Square	F	Sig
Corrected Model	599.299[a]	7	85.614	1.887	0.086
Intercept	26457.929	1	26457.929	583.115	0
n_gender_robot	139 406	1	139.406	3.072	0.084
n_gender_subject	122 327	1	122.327	2.696	0.105
subject_alone	38.912	1	38.912	0.858	0.358
n_gender_robot * n_gender_subject	166 216	1	166 216	3.663	0.06
n_gender_robot * subject_alone	3 029	1	3.029	0.067	0 797
n_gender_subject * subject_alone	0 32	1	0.32	0 007	0.933
n_gender_robot * n_gender_subject * subject_alone	22.076	1	22.076	0 487	0.488
Error	2994.647	66	45 373		
Total	36312	74			
Corrected Total	3593.946	73			

a. R Squared = .167 (Adjusted R Squared = 078)

Tests of Between-Subjects Effects

Dependent Variable.happiness

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2793.643[a]	7	399.092	1.546	0.172
Intercept	438645.064	1	438645.064	1699 13	0
n_gender_robot	488.71	1	488.71	1.893	0.175
n_gender_subject	16.305	1	16.305	0.063	0.803
subject_alone	842.195	1	842.195	3.262	0.076

n_gender_robot * n_gender_subject	304 811	1	304 811	1.181	0 282
n_gender_robot * subject_alone	53 165	1	53.165	0 206	0.652
n_gender_subject * subject_alone	1022.954	1	1022.954	3 963	0.052
n_gender_robot * n_gender_subject * subject_alone	402.938	1	402 938	1.561	0 217
Error	13940.567	54	258.159		
Total	574955	62			
Corrected Total	16734 21	61			
a R Squared = .167 (Adjusted R Squared = 059)					

Tests of Between-Subjects Effects

Dependent Variable:happiness

Source	Type III Sum of Squares	df	Mean Square	F	Sig
Corrected Model	638 442[a]	3	212.814	0.776	0 512
Intercept	531302 384	1	531302.384	1937.682	0
n_gender_subject	24 727	1	24 727	0.09	0 765
n_gender_robot	88	1	88	0.321	0 573
n_gender_subject * n_gender_robot	477.87	1	477 87	1.743	0.192
Error	16177 494	59	274 195		
Total	585771	63			
Corrected Total	16815.937	62			
a. R Squared = 038 (Adjusted R Squared = - 011)					

Tests of Between-Subjects Effects

Dependent Variable.time spent on questionnaire

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3.40E+11	7	4 86E+10	1.837	0.092
Intercept	1.06E+13	1	1 06E+13	401 721	0
n_gender_robot	1.28E+10	1	1 28E+10	0.483	0 489
n_gender_subject	1 18E+09	1	1 18E+09	0.045	0.833
subject_alone	1.34E+11	1	1.34E+11	5.057	0.027
n_gender_robot * n_gender_subject	3 93E+10	1	3 93E+10	1 485	0 227
n_gender_robot * subject_alone	9.97E+09	1	9.97E+09	0 377	0.541
n_gender_subject * subject_alone	4 37E+10	1	4 37E+10	1.653	0.202
n_gender_robot * n_gender_subject * subject_alone	1 52E+10	1	1 52E+10	0 576	0.45
Error	2 09E+12	79	2 64E+10		
Total	1.65E+13	87			
Corrected Total	2 43E+12	86			
a R Squared = 140 (Adjusted R Squared = 064)					

Tests of Between-Subjects Effects

Dependent Variable:time spent on questionnaire

Source	Type III Sum of Squares	df	Mean Square	F	Sig
Corrected Model	8 26E+10	3	2 75E+10	0.985	0.404
Intercept	1 32E+13	1	1.32E+13	472 988	0
n_gender_subject	5 34E+09	1	5 34E+09	0.191	0.663
n_gender_robot	4 79E+10	1	4.79E+10	1 714	0.194
n_gender_subject * n_gender_robot	4 66E+10	1	4.66E+10	1 669	0 2
Error	2.35E+12	84	2 79E+10		
Total	1 67E+13	88			
Corrected Total	2 43E+12	87			
a. R Squared = 034 (Adjusted R Squared = - 001)					

Tests of Between-Subjects Effects

Dependent Variable:questions answered

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	9388 492[a]	7	1341.213	2 84	0.011
Intercept	267719.467	1	267719 467	566 967	0
n_gender_robot	245.467	1	245.467	0.52	0.473
n_gender_subject	104.968	1	104 968	0 222	0 639
subject_alone	6927 428	1	6927 428	14.671	0

n_gender_robot * n_gender_subject	0.358	1	0.358	0.001	0.978
n_gender_robot * subject_alone	214 502	1	214.502	0.454	0.502
n_gender_subject * subject_alone	0.386	1	0.386	0.001	0 977
n_gender_robot * n_gender_subject * subject_alone	68.506	1	68.506	0.145	0.704
Error	37303.462	79	472.196		
Total	392247	87			
Corrected Total	46691.954	86			

a. R Squared = .201 (Adjusted R Squared = .130)

Tests of Between-Subjects Effects

Dependent Variable:questions answered

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1596.845[a]	3	532.282	0.988	0.402
Intercept	326694.36	1	326694 36	606.636	0
n_gender_subject	70 33	1	70.33	0.131	0 719
n_gender_robot	1556 546	1	1556.546	2.89	0.093
n_gender_subject * n_gender_robot	115 171	1	115.171	0.214	0.645
Error	45236 928	84	538.535		
Total	397872	88			
Corrected Total	46833.773	87			

a. R Squared = 034 (Adjusted R Squared = .000)

Perceived Autonomy

Tests of Between-Subjects Effects

Dependent Variable.gave donation

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1 756[a]	7	0 251	1.075	0 388
Intercept	25.078	1	25 078	107.467	0
curtain_up	0.794	1	0.794	3.403	0.069
n_gender_subject	0.434	1	0 434	1 859	0.177
subject_alone	0.14	1	0 14	0.601	0.441
curtain_up * n_gender_subject	0.003	1	0.003	0.013	0.91
curtain_up * subject_alone	0 053	1	0.053	0.226	0.636
n_gender_subject * subject_alone	0 291	1	0.291	1.247	0 268
curtain_up * n_gender_subject * subject_alone	0 02	1	0.02	0.086	0.77
Error	17.268	74	0 233		
Total	52	82			
Corrected Total	19.024	81			

a. R Squared = .092 (Adjusted R Squared = .006)

Tests of Between-Subjects Effects

Dependent Variable:gave donation

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1.144[a]	3	0 381	1.664	0.182
Intercept	32.451	1	32.451	141.564	0
n_gender_subject	0.344	1	0.344	1.502	0.224
curtain_up	0.726	1	0.726	3.168	0.079
n_gender_subject * curtain_up	0.02	1	0.02	0.089	0.766
Error	17.88	78	0.229		
Total	52	82			
Corrected Total	19.024	81			

a. R Squared = 060 (Adjusted R Squared = 024)

Tests of Between-Subjects Effects

Dependent Variable:donation

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	39.939[a]	7	5.706	1.044	0.408

Intercept	462.393	1	462.393	84.591	0
curtain_up	26.337	1	26.337	4.818	0.031
n_gender_subject	10.475	1	10.475	1.916	0.17
subject_alone	4.63	1	4.63	0.847	0.36
curtain_up * n_gender_subject	0.088	1	0.088	0.016	0.9
curtain_up * subject_alone	0.001	1	0.001	0	0.987
n_gender_subject * subject_alone	2.954	1	2.954	0.54	0.465
curtain_up * n_gender_subject * subject_alone	9.718	1	9.718	1.778	0.187
Error	404.5	74	5.466		
Total	1024	82			
Corrected Total	444.439	81			

a. R Squared = .090 (Adjusted R Squared = .004)

Tests of Between-Subjects Effects

Dependent Variable:donation

Source	Type III Sum of Squares	df	Mean Square	F	Sig
Corrected Model	26.032[a]	3	8.677	1.618	0.192
Intercept	574.379	1	574.379	107.077	0
n_gender_subject	3.779	1	3.779	0.704	0.404
curtain_up	19.625	1	19.625	3.659	0.059
n_gender_subject * curtain_up	0.665	1	0.665	0.124	0.726
Error	418.407	78	5.364		
Total	1024	82			
Corrected Total	444.439	81			

a. R Squared = .059 (Adjusted R Squared = .022)

Tests of Between-Subjects Effects

Dependent Variable:credibility

Source	Type III Sum of Squares	df	Mean Square	F	Sig
Corrected Model	1307.085[a]	7	186.726	1.279	0.273
Intercept	305982.412	1	305982.412	2096.509	0
curtain_up	26.015	1	26.015	0.178	0.674
n_gender_subject	17.156	1	17.156	0.118	0.733
subject_alone	202.88	1	202.88	1.39	0.242
curtain_up * n_gender_subject	532.776	1	532.776	3.65	0.06
curtain_up * subject_alone	41.863	1	41.863	0.287	0.594
n_gender_subject * subject_alone	484.495	1	484.495	3.32	0.073
curtain_up * n_gender_subject * subject_alone	315.306	1	315.306	2.16	0.146
Error	10070.447	69	145.949		
Total	472078	77			
Corrected Total	11377.532	76			

a. R Squared = .115 (Adjusted R Squared = .025)

Tests of Between-Subjects Effects

Dependent Variable:credibility

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	659.403[a]	3	219.801	1.497	0.223
Intercept	422763.245	1	422763.245	2879.394	0
n_gender_subject	297.599	1	297.599	2.027	0.159
curtain_up	23.71	1	23.71	0.161	0.689
n_gender_subject * curtain_up	184.438	1	184.438	1.256	0.266
Error	10718.13	73	146.824		
Total	472078	77			
Corrected Total	11377.532	76			

a. R Squared = .058 (Adjusted R Squared = .019)

Tests of Between-Subjects Effects

Dependent Variable:credibility - safety

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	54.527[a]	7	7.79	0.343	0.931

Intercept	45431.865	1	45431.865	1998.986	0
curtain_up	1.868	1	1.868	0.082	0.775
n_gender_subject	1.043	1	1.043	0.046	0.831
subject_alone	0.021	1	0.021	0.001	0.976
curtain_up * n_gender_subject	12.509	1	12.509	0.55	0.461
curtain_up * subject_alone	1.941	1	1.941	0.085	0.771
n_gender_subject * subject_alone	15.217	1	15.217	0.67	0.416
curtain_up * n_gender_subject * subject_alone	22.267	1	22.267	0.98	0.326
Error	1590.922	70	22.727		
Total	69643	78			
Corrected Total	1645.449	77			

a. R Squared = .033 (Adjusted R Squared = -.064)

Tests of Between-Subjects Effects

Dependent Variable:credibility - safety

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	21.153[a]	3	7.051	0.321	0.81
Intercept	61772.565	1	61772.565	2814.248	0
n_gender_subject	13.529	1	13.529	0.616	0.435
curtain_up	0.386	1	0.386	0.018	0.895
n_gender_subject * curtain_up	2.795	1	2.795	0.127	0.722
Error	1624.295	74	21.95		
Total	69643	78			
Corrected Total	1645.449	77			

a. R Squared = .013 (Adjusted R Squared = -.027)

Tests of Between-Subjects Effects

Dependent Variable:credibility - qualification

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	369.737[a]	7	52.82	1.668	0.131
Intercept	38047.49	1	38047.49	1201.601	0
curtain_up	5.738	1	5.738	0.181	0.672
n_gender_subject	1.443	1	1.443	0.046	0.832
subject_alone	49.39	1	49.39	1.56	0.216
curtain_up * n_gender_subject	163.729	1	163.729	5.171	0.026
curtain_up * subject_alone	16.861	1	16.861	0.533	0.468
n_gender_subject * subject_alone	112.596	1	112.596	3.556	0.063
curtain_up * n_gender_subject * subject_alone	114.104	1	114.104	3.604	0.062
Error	2216.48	70	31.664		
Total	60697	78			
Corrected Total	2586.218	77			

a. R Squared = .143 (Adjusted R Squared = .057)

Tests of Between-Subjects Effects

Dependent Variable:credibility - qualification

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	196.373[a]	3	65.458	2.027	0.117
Intercept	53239.332	1	53239.332	1648.522	0
n_gender_subject	72.071	1	72.071	2.232	0.139
curtain_up	8.138	1	8.138	0.252	0.617
n_gender_subject * curtain_up	67.287	1	67.287	2.083	0.153
Error	2389.845	74	32.295		
Total	60697	78			
Corrected Total	2586.218	77			

a. R Squared = .076 (Adjusted R Squared = .038)

Tests of Between-Subjects Effects

Dependent Variable:credibility - dynamism

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	171.371[a]	7	24.482	1.223	0.302

Intercept	21770.53	1	21770.53	1087.621	0
curtain_up	2.714	1	2.714	0.136	0.714
n_gender_subject	4.927	1	4.927	0.246	0.621
subject_alone	59.082	1	59.082	2.952	0.09
curtain_up * n_gender_subject	50.833	1	50.833	2.54	0.116
curtain_up * subject_alone	0.51	1	0.51	0.025	0.874
n_gender_subject * subject_alone	61.924	1	61.924	3.094	0.083
curtain_up * n_gender_subject * subject_alone	4.646	1	4.646	0.232	0.632
Error	1381.148	69	20.017		
Total	34220	77			
Corrected Total	1552.519	76			

a. R Squared = .110 (Adjusted R Squared = .020)

Tests of Between-Subjects Effects

Dependent Variable credibility - dynamism

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	65.750[a]	3	21.917	1.076	0.365
Intercept	30089.357	1	30089.357	1477.38	0
n_gender_subject	29.201	1	29.201	1.434	0.235
curtain_up	5.691	1	5.691	0.279	0.599
n_gender_subject * curtain_up	16.125	1	16.125	0.792	0.377
Error	1486.769	73	20.367		
Total	34220	77			
Corrected Total	1552.519	76			

a. R Squared = .042 (Adjusted R Squared = .003)

Tests of Between-Subjects Effects

Dependent Variable trust

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	873.258[a]	7	124.751	0.789	0.599
Intercept	314518.489	1	314518.489	1989.663	0
curtain_up	0.85	1	0.85	0.005	0.942
n_gender_subject	15.413	1	15.413	0.098	0.756
subject_alone	66.499	1	66.499	0.421	0.519
curtain_up * n_gender_subject	436.327	1	436.327	2.76	0.101
curtain_up * subject_alone	191.634	1	191.634	1.212	0.275
n_gender_subject * subject_alone	77.219	1	77.219	0.488	0.487
curtain_up * n_gender_subject * subject_alone	122.574	1	122.574	0.775	0.382
Error	10907.262	69	158.076		
Total	487452	77			
Corrected Total	11780.519	76			

a. R Squared = .074 (Adjusted R Squared = -.020)

Tests of Between-Subjects Effects

Dependent Variable trust

Source	Type III Sum of Squares	df	Mean Square	F	Sig
Corrected Model	622.327[a]	3	207.442	1.357	0.263
Intercept	435292.388	1	435292.388	2847.804	0
n_gender_subject	149.192	1	149.192	0.976	0.326
curtain_up	34.33	1	34.33	0.225	0.637
n_gender_subject * curtain_up	282.794	1	282.794	1.85	0.178
Error	11158.192	73	152.852		
Total	487452	77			
Corrected Total	11780.519	76			

a. R Squared = .053 (Adjusted R Squared = .014)

Tests of Between-Subjects Effects

Dependent Variable engagement

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	560.911[a]	7	80.13	1.759	0.11

Intercept	22957.097	1	22957.097	504 021	0
curtain_up	68.295	1	68.295	1.499	0.225
n_gender_subject	110 038	1	110.038	2.416	0.125
subject_alone	25.29	1	25.29	0.555	0.459
curtain_up * n_gender_subject	150.21	1	150.21	3.298	0.074
curtain_up * subject_alone	0.575	1	0 575	0.013	0.911
n_gender_subject * subject_alone	47.54	1	47 54	1.044	0.311
curtain_up * n_gender_subject * subject_alone	3 595	1	3.595	0 079	0.78
Error	3142.804	69	45.548		
Total	36743	77			
Corrected Total	3703.714	76			
a R Squared = 151 (Adjusted R Squared = 065)					

Tests of Between-Subjects Effects

Dependent Variable:engagement

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	451.838[a]	3	150.613	3.381	0.023
Intercept	31068.62	1	31068.62	697.446	0
n_gender_subject	162.922	1	162 922	3 657	0.06
curtain_up	59.964	1	59.964	1.346	0.25
n_gender_subject * curtain_up	124 694	1	124 694	2.799	0.099
Error	3251.876	73	44.546		
Total	36743	77			
Corrected Total	3703.714	76			
a. R Squared = .122 (Adjusted R Squared = 086)					

Tests of Between-Subjects Effects

Dependent Variable:happiness

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2455.548[a]	7	350.793	1.443	0.209
Intercept	353529.76	1	353529.76	1453.877	0
curtain_up	12 642	1	12.642	0 052	0.821
n_gender_subject	160 655	1	160.655	0.661	0.42
subject_alone	864.007	1	864.007	3.553	0 065
curtain_up * n_gender_subject	635 758	1	635.758	2.615	0.112
curtain_up * subject_alone	20.544	1	20.544	0.084	0 772
n_gender_subject * subject_alone	128.095	1	128.095	0.527	0.471
curtain_up * n_gender_subject * subject_alone	0.036	1	0.036	0	0.99
Error	12401.333	51	243.163		
Total	521620	59			
Corrected Total	14856.881	58			
a R Squared = 165 (Adjusted R Squared = 051)					

Tests of Between-Subjects Effects

Dependent Variable:happiness

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1267 589[a]	3	422.53	1.71	0.176
Intercept	435439.308	1	435439.308	1762.355	0
n_gender_subject	296.389	1	296.389	1 2	0.278
curtain_up	293.741	1	293.741	1.189	0.28
n_gender_subject * curtain_up	1096.001	1	1096.001	4.436	0 04
Error	13589.293	55	247.078		
Total	521620	59			
Corrected Total	14856.881	58			
a. R Squared = .085 (Adjusted R Squared = 035)					

Tests of Between-Subjects Effects

Dependent Variable:time spent on questionnaire

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2.71E+11	7	3 88E+10	1 977	0 07

Intercept	1.11E+13	1	1.11E+13	565.496	0
curtain_up	8.24E+10	1	8.24E+10	4.201	0.044
n_gender_subject	1.07E+10	1	1.07E+10	0.546	0.462
subject_alone	3.49E+09	1	3.49E+09	0.178	0.674
curtain_up * n_gender_subject	1.13E+10	1	1.13E+10	0.578	0.45
curtain_up * subject_alone	3.27E+10	1	3.27E+10	1.667	0.201
n_gender_subject * subject_alone	4.53E+09	1	4.53E+09	0.231	0.632
curtain_up * n_gender_subject * subject_alone	5.42E+10	1	5.42E+10	2.762	0.101
Error	1.45E+12	74	1.96E+10		
Total	1.81E+13	82			
Corrected Total	1.72E+12	81			
a. R Squared = .158 (Adjusted R Squared = .078)					

Tests of Between-Subjects Effects					
Dependent Variable:time spent on questionnaire					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1.14E+11	3	3.79E+10	1.839	0.147
Intercept	1.51E+13	1	1.51E+13	732.597	0
n_gender_subject	1.39E+09	1	1.39E+09	0.067	0.796
curtain_up	8.53E+10	1	8.53E+10	4.134	0.045
n_gender_subject * curtain_up	9.20E+09	1	9.20E+09	0.446	0.506
Error	1.61E+12	78	2.06E+10		
Total	1.81E+13	82			
Corrected Total	1.72E+12	81			
a. R Squared = .066 (Adjusted R Squared = .030)					

Tests of Between-Subjects Effects					
Dependent Variable:questions answered					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3949.767[a]	7	564.252	2.14	0.05
Intercept	251314.22	1	251314.22	953.103	0
curtain_up	408.256	1	408.256	1.548	0.217
n_gender_subject	299.215	1	299.215	1.135	0.29
subject_alone	682.571	1	682.571	2.589	0.112
curtain_up * n_gender_subject	56.424	1	56.424	0.214	0.645
curtain_up * subject_alone	1279.64	1	1279.64	4.853	0.031
n_gender_subject * subject_alone	51.179	1	51.179	0.194	0.661
curtain_up * n_gender_subject * subject_alone	197.776	1	197.776	0.75	0.389
Error	19512.331	74	263.68		
Total	399644	82			
Corrected Total	23462.098	81			
a. R Squared = .168 (Adjusted R Squared = .090)					

Tests of Between-Subjects Effects					
Dependent Variable:questions answered					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	303.938[a]	3	101.313	0.341	0.796
Intercept	341788.331	1	341788.331	1151.192	0
n_gender_subject	123.67	1	123.67	0.417	0.521
curtain_up	212.062	1	212.062	0.714	0.401
n_gender_subject * curtain_up	79.788	1	79.788	0.269	0.606
Error	23158.16	78	296.899		
Total	399644	82			
Corrected Total	23462.098	81			
a. R Squared = .013 (Adjusted R Squared = -.025)					

Touch and Robot Gender

Tests of Between-Subjects Effects	
Dependent Variable:gave donation	

Source	Squares	df	Mean Square	F	Sig.
Corrected Model	9.756[a]	15	0.65	3.975	0
Intercept	46.95	1	46.95	286.927	0
n_hand_shake	0.023	1	0.023	0.142	0.707
n_gender_robot	0.156	1	0.156	0.952	0.33
n_gender_subject	0.124	1	0.124	0.758	0.385
subject_alone	1.489	1	1.489	9.102	0.003
n_hand_shake * n_gender_robot	0.675	1	0.675	4.123	0.044
n_hand_shake * n_gender_subject	0.064	1	0.064	0.392	0.532
n_hand_shake * subject_alone	2.305	1	2.305	14.084	0
n_gender_robot * n_gender_subject	0.018	1	0.018	0.112	0.739
n_gender_robot * subject_alone	0.148	1	0.148	0.902	0.344
n_gender_subject * subject_alone	0.306	1	0.306	1.869	0.173
n_hand_shake * n_gender_robot * n_gender_subject	0.59	1	0.59	3.606	0.059
n_hand_shake * n_gender_robot * subject_alone	0.015	1	0.015	0.092	0.762
n_hand_shake * n_gender_subject * subject_alone	0.047	1	0.047	0.289	0.591
n_gender_robot * n_gender_subject * subject_alone	0.039	1	0.039	0.24	0.624
n_hand_shake * n_gender_robot * n_gender_subject * subject_alone	0.444	1	0.444	2.713	0.101
Error	29.29	179	0.164		
Total	141	195			
Corrected Total	39.046	194			
a. R Squared = .250 (Adjusted R Squared = .187)					

Tests of Between-Subjects Effects

Dependent Variable:gave donation

Source	Squares	df	Mean Square	F	Sig.
Corrected Model	4.002[a]	7	0.572	3.08	0.004
Intercept	58.314	1	58.314	314.132	0
n_hand_shake	0.014	1	0.014	0.074	0.786
n_gender_robot	0.941	1	0.941	5.069	0.026
n_gender_subject	0.001	1	0.001	0.007	0.933
n_hand_shake * n_gender_robot	0.179	1	0.179	0.962	0.328
n_hand_shake * n_gender_subject	0.044	1	0.044	0.24	0.625
n_gender_robot * n_gender_subject	0.162	1	0.162	0.875	0.351
n_hand_shake * n_gender_robot * n_gender_subject	1.325	1	1.325	7.138	0.008
Error	35.271	190	0.186		
Total	144	198			
Corrected Total	39.273	197			
a. R Squared = .102 (Adjusted R Squared = .069)					

Tests of Between-Subjects Effects

Dependent Variable donation

Source	Squares	df	Mean Square	F	Sig.
Corrected Model	172.554[a]	15	11.504	2.618	0.001
Intercept	785.747	1	785.747	178.795	0
n_hand_shake	11.606	1	11.606	2.641	0.106
n_gender_robot	0.01	1	0.01	0.002	0.963
n_gender_subject	3.153	1	3.153	0.717	0.398
subject_alone	40.537	1	40.537	9.224	0.003
n_hand_shake * n_gender_robot	7.397	1	7.397	1.683	0.196
n_hand_shake * n_gender_subject	4.007	1	4.007	0.912	0.341
n_hand_shake * subject_alone	44.885	1	44.885	10.213	0.002
n_gender_robot * n_gender_subject	0.108	1	0.108	0.024	0.876
n_gender_robot * subject_alone	1.619	1	1.619	0.368	0.545
n_gender_subject * subject_alone	8.402	1	8.402	1.912	0.168
n_hand_shake * n_gender_robot * n_gender_subject	11.306	1	11.306	2.573	0.11
n_hand_shake * n_gender_robot * subject_alone	1.465	1	1.465	0.333	0.564
n_hand_shake * n_gender_subject * subject_alone	0.924	1	0.924	0.21	0.647
n_gender_robot * n_gender_subject * subject_alone	7.169	1	7.169	1.631	0.203
n_hand_shake * n_gender_robot * n_gender_subject * subject_alone	7.571	1	7.571	1.723	0.191
Error	786.646	179	4.395		
Total	2488	195			
Corrected Total	959.2	194			

a R Squared = .180 (Adjusted R Squared = 111)

Tests of Between-Subjects Effects

Dependent Variable:donation

Source	Squares	df	Mean Square	F	Sig
Corrected Model	52 673^a	7	7 525	1 558	0 15
Intercept	942 844	1	942 844	195 177	0
n_hand_shake	8 797	1	8 797	1 821	0.179
n_gender_robot	4 575	1	4.575	0.947	0.332
n_gender_subject	1.947	1	1 947	0.403	0.526
n_hand_shake * n_gender_robot	0 799	1	0 799	0.165	0 685
n_hand_shake * n_gender_subject	2 727	1	2 727	0 564	0 453
n_gender_robot * n_gender_subject	5 127	1	5 127	1.061	0 304
n_hand_shake * n_gender_robot * n_gender_subject	30.229	1	30 229	6 258	0 013
Error	917.837	190	4 831		
Total	2515	198			
Corrected Total	970.51	197			

a R Squared = .054 (Adjusted R Squared = .019)

Tests of Between-Subjects Effects

Dependent Variable:credibility

Source	Squares	df	Mean Square	F	Sig.
Corrected Model	2403.824^a	15	160 255	0 944	0 517
Intercept	584227 037	1	584227.037	3441 06	0
n_hand_shake	303.087	1	303 087	1.785	0 183
n_gender_robot	8.709	1	8.709	0.051	0 821
n_gender_subject	327.938	1	327 938	1.932	0 167
subject_alone	234.803	1	234.803	1.383	0 241
n_hand_shake * n_gender_robot	38.127	1	38 127	0.225	0 636
n_hand_shake * n_gender_subject	72.082	1	72 082	0.425	0 516
n_hand_shake * subject_alone	44 389	1	44 389	0 261	0.61
n_gender_robot * n_gender_subject	14 556	1	14 556	0 086	0.77
n_gender_robot * subject_alone	315 169	1	315 169	1.856	0.175
n_gender_subject * subject_alone	15.81	1	15.81	0.093	0.761
n_hand_shake * n_gender_robot * n_gender_subject	535 841	1	535.841	3.156	0.078
n_hand_shake * n_gender_robot * subject_alone	254 982	1	254 982	1.502	0.222
n_hand_shake * n_gender_subject * subject_alone	10 729	1	10 729	0.063	0.802
n_gender_robot * n_gender_subject * subject_alone	314 487	1	314 487	1.852	0 175
n_hand_shake * n_gender_robot * n_gender_subject * subject_alone	128 058	1	128.058	0 754	0 386
Error	26825.417	158	169.781		
Total	1 08E+06	174			
Corrected Total	29229 241	173			

a. R Squared = 082 (Adjusted R Squared = -.005)

Tests of Between-Subjects Effects

Dependent Variable:credibility

Source	Squares	df	Mean Square	F	Sig
Corrected Model	1313.437^a	7	187 634	1.134	0.344
Intercept	677061 28	1	677061.28	4090.743	0
n_hand_shake	87.263	1	87 263	0 527	0.469
n_gender_robot	26.736	1	26 736	0 162	0.688
n_gender_subject	157.599	1	157.599	0 952	0.331
n_hand_shake * n_gender_robot	31.389	1	31.389	0 19	0 664
n_hand_shake * n_gender_subject	6.847	1	6.847	0 041	0 839
n_gender_robot * n_gender_subject	47.465	1	47 465	0.287	0 593
n_hand_shake * n_gender_robot * n_gender_subject	486.644	1	486.644	2.94	0 088
Error	27971.286	169	165.511		
Total	1.10E+06	177			
Corrected Total	29284 723	176			

a R Squared = .045 (Adjusted R Squared = .005)

Tests of Between-Subjects Effects

Dependent Variable:credibility - safety

Source	Squares	df	Mean Square	F	Sig.
Corrected Model	334.910[a]	15	22.327	0.87	0.598
Intercept	86301.289	1	86301.289	3363.598	0
n_hand_shake	54.278	1	54.278	2.116	0.148
n_gender_robot	0.717	1	0.717	0.028	0.867
n_gender_subject	6.737	1	6.737	0.263	0.609
subject_alone	6.569	1	6.569	0.256	0.614
n_hand_shake * n_gender_robot	2.818	1	2.818	0.11	0.741
n_hand_shake * n_gender_subject	28.316	1	28.316	1.104	0.295
n_hand_shake * subject_alone	27.43	1	27.43	1.069	0.303
n_gender_robot * n_gender_subject	0.225	1	0.225	0.009	0.926
n_gender_robot * subject_alone	38.042	1	38.042	1.483	0.225
n_gender_subject * subject_alone	0.81	1	0.81	0.032	0.859
n_hand_shake * n_gender_robot * n_gender_subject	70.409	1	70.409	2.744	0.1
n_hand_shake * n_gender_robot * subject_alone	30.956	1	30.956	1.207	0.274
n_hand_shake * n_gender_subject * subject_alone	0.049	1	0.049	0.002	0.965
n_gender_robot * n_gender_subject * subject_alone	41.642	1	41.642	1.623	0.204
n_hand_shake * n_gender_robot * n_gender_subject * subject_alone	41.396	1	41.396	1.613	0.206
Error	4233.477	165	25.657		
Total	162822	181			
Corrected Total	4568.387	180			
a. R Squared = .073 (Adjusted R Squared = -.011)					

Tests of Between-Subjects Effects

Dependent Variable:credibility - safety

Source	Squares	df	Mean Square	F	Sig.
Corrected Model	190.093[a]	7	27.156	1.077	0.38
Intercept	100338.496	1	100338.496	3978.966	0
n_hand_shake	24.08	1	24.08	0.955	0.33
n_gender_robot	0.206	1	0.206	0.008	0.928
n_gender_subject	0.201	1	0.201	0.008	0.929
n_hand_shake * n_gender_robot	6.416	1	6.416	0.254	0.615
n_hand_shake * n_gender_subject	9.711	1	9.711	0.385	0.536
n_gender_robot * n_gender_subject	0.517	1	0.517	0.02	0.886
n_hand_shake * n_gender_robot * n_gender_subject	75.857	1	75.857	3.008	0.085
Error	4438.233	176	25.217		
Total	166292	184			
Corrected Total	4628.326	183			
a. R Squared = .041 (Adjusted R Squared = .003)					

Tests of Between-Subjects Effects

Dependent Variable credibility - qualification

Source	Squares	df	Mean Square	F	Sig.
Corrected Model	603.872[a]	15	40.258	1.011	0.446
Intercept	72729.85	1	72729.85	1826.44	0
n_hand_shake	45.384	1	45.384	1.14	0.287
n_gender_robot	13.305	1	13.305	0.334	0.564
n_gender_subject	164.177	1	164.177	4.123	0.044
subject_alone	31.423	1	31.423	0.789	0.376
n_hand_shake * n_gender_robot	44.207	1	44.207	1.11	0.294
n_hand_shake * n_gender_subject	17.255	1	17.255	0.433	0.511
n_hand_shake * subject_alone	2.363	1	2.363	0.059	0.808
n_gender_robot * n_gender_subject	15.505	1	15.505	0.389	0.533
n_gender_robot * subject_alone	54.003	1	54.003	1.356	0.246
n_gender_subject * subject_alone	27.221	1	27.221	0.684	0.41
n_hand_shake * n_gender_robot * n_gender_subject	39.132	1	39.132	0.983	0.323
n_hand_shake * n_gender_robot * subject_alone	55.981	1	55.981	1.406	0.237
n_hand_shake * n_gender_subject * subject_alone	0.012	1	0.012	0	0.986
n_gender_robot * n_gender_subject * subject_alone	57.93	1	57.93	1.455	0.229
n_hand_shake * n_gender_robot * n_gender_subject * subject_alone	5.665	1	5.665	0.142	0.707
Error	6570.393	165	39.821		
Total	140531	181			
Corrected Total	7174.265	180			

a R Squared = 084 (Adjusted R Squared = .001)

Tests of Between-Subjects Effects

Dependent Variable credibility - qualification

Source	Squares	df	Mean Square	F	Sig
Corrected Model	342.395[a]	7	48.914	1 258	0.274
Intercept	83501.539	1	83501.539	2147.12	0
n_hand_shake	10 248	1	10.248	0 264	0 608
n_gender_robot	17.872	1	17.872	0.46	0 499
n_gender_subject	124.079	1	124.079	3 191	0 076
n_hand_shake * n_gender_robot	41 182	1	41 182	1 059	0 305
n_hand_shake * n_gender_subject	6.561	1	6.561	0.169	0 682
n_gender_robot * n_gender_subject	42.113	1	42 113	1.083	0 299
n_hand_shake * n_gender_robot * n_gender_subject	36 306	1	36 306	0 934	0 335
Error	6844.643	176	38 89		
Total	142785	184			
Corrected Total	7187.038	183			

a R Squared = 048 (Adjusted R Squared = .010)

Tests of Between-Subjects Effects

Dependent Variable.credibility - dynamism

Source	Squares	df	Mean Square	F	Sig
Corrected Model	236.987[a]	15	15.799	0 651	0.829
Intercept	42543.4	1	42543.4	1751 857	0
n_hand_shake	10.537	1	10 537	0.434	0.511
n_gender_robot	0 436	1	0 436	0.018	0 894
n_gender_subject	7 17	1	7.17	0 295	0 588
subject_alone	37 154	1	37.154	1 53	0 218
n_hand_shake * n_gender_robot	3 502	1	3.502	0 144	0 705
n_hand_shake * n_gender_subject	2 151	1	2.151	0 089	0.766
n_hand_shake * subject_alone	0 132	1	0.132	0 005	0 941
n_gender_robot * n_gender_subject	0 001	1	0.001	0	0.995
n_gender_robot * subject_alone	34 286	1	34.286	1 412	0 237
n_gender_subject * subject_alone	2.75	1	2.75	0.113	0.737
n_hand_shake * n_gender_robot * n_gender_subject	71 369	1	71.369	2 939	0.088
n_hand_shake * n_gender_robot * subject_alone	4.92	1	4 92	0.203	0.653
n_hand_shake * n_gender_subject * subject_alone	6.079	1	6.079	0 25	0.618
n_gender_robot * n_gender_subject * subject_alone	21 186	1	21 186	0 872	0 352
n_hand_shake * n_gender_robot * n_gender_subject * subject_alone	1 1	1	1 1	0.045	0.832
Error	3836 99	158	24 285		
Total	80892	174			
Corrected Total	4073.977	173			

a R Squared = 058 (Adjusted R Squared = - 031)

Tests of Between-Subjects Effects

Dependent Variable:credibility - dynamism

Source	Squares	df	Mean Square	F	Sig
Corrected Model	120.211[a]	7	17.173	0 721	0.654
Intercept	49015.533	1	49015 533	2057.363	0
n_hand_shake	2 035	1	2.035	0.085	0.77
n_gender_robot	1.901	1	1.901	0.08	0.778
n_gender_subject	0 341	1	0.341	0.014	0.905
n_hand_shake * n_gender_robot	7 938	1	7.938	0.333	0.565
n_hand_shake * n_gender_subject	8 957	1	8.957	0.376	0 541
n_gender_robot * n_gender_subject	0 27	1	0.27	0.011	0 915
n_hand_shake * n_gender_robot * n_gender_subject	60 594	1	60.594	2.543	0.113
Error	4026.331	169	23.824		
Total	81826	177			
Corrected Total	4146.542	176			

a R Squared = 029 (Adjusted R Squared = - 011)

Tests of Between-Subjects Effects

Dependent Variable trust

Source	Squares	df	Mean Square	F	Sig.
Corrected Model	3022.934[a]	15	201.529	1.011	0.447
Intercept	623910.367	1	623910.367	3129.233	0
n_hand_shake	816.4	1	816.4	4.095	0.045
n_gender_robot	51.165	1	51.165	0.257	0.613
n_gender_subject	87.325	1	87.325	0.438	0.509
subject_alone	78.81	1	78.81	0.395	0.53
n_hand_shake * n_gender_robot	2.957	1	2.957	0.015	0.903
n_hand_shake * n_gender_subject	69.873	1	69.873	0.35	0.555
n_hand_shake * subject_alone	285.779	1	285.779	1.433	0.233
n_gender_robot * n_gender_subject	40.562	1	40.562	0.203	0.653
n_gender_robot * subject_alone	458.598	1	458.598	2.3	0.131
n_gender_subject * subject_alone	10.658	1	10.658	0.053	0.817
n_hand_shake * n_gender_robot * n_gender_subject	669.952	1	669.952	3.36	0.069
n_hand_shake * n_gender_robot * subject_alone	441.29	1	441.29	2.213	0.139
n_hand_shake * n_gender_subject * subject_alone	23.163	1	23.163	0.116	0.734
n_gender_robot * n_gender_subject * subject_alone	75.278	1	75.278	0.378	0.54
n_hand_shake * n_gender_robot * n_gender_subject * subject_alone	176.453	1	176.453	0.885	0.348
Error	30106.563	151	199.381		
Total	1.11E+06	167			
Corrected Total	33129.497	166			

a. R Squared = .091 (Adjusted R Squared = .001)

Tests of Between-Subjects Effects

Dependent Variable:trust

Source	Squares	df	Mean Square	F	Sig.
Corrected Model	1969.551[a]	7	281.364	1.435	0.195
Intercept	723745.841	1	723745.841	3691.311	0
n_hand_shake	402.224	1	402.224	2.051	0.154
n_gender_robot	118.621	1	118.621	0.605	0.438
n_gender_subject	40.213	1	40.213	0.205	0.651
n_hand_shake * n_gender_robot	0.514	1	0.514	0.003	0.959
n_hand_shake * n_gender_subject	5.723	1	5.723	0.029	0.865
n_gender_robot * n_gender_subject	70.097	1	70.097	0.358	0.551
n_hand_shake * n_gender_robot * n_gender_subject	581.075	1	581.075	2.964	0.087
Error	31762.925	162	196.067		
Total	1.14E+06	170			
Corrected Total	33732.476	169			

a. R Squared = .058 (Adjusted R Squared = .018)

Tests of Between-Subjects Effects

Dependent Variable:engagement

Source	Squares	df	Mean Square	F	Sig.
Corrected Model	1008.472[a]	15	67.231	1.958	0.022
Intercept	43767.61	1	43767.61	1274.871	0
n_hand_shake	44.008	1	44.008	1.282	0.259
n_gender_robot	0.349	1	0.349	0.01	0.92
n_gender_subject	47.468	1	47.468	1.383	0.242
subject_alone	5.795	1	5.795	0.169	0.682
n_hand_shake * n_gender_robot	292.329	1	292.329	8.515	0.004
n_hand_shake * n_gender_subject	44.265	1	44.265	1.289	0.258
n_hand_shake * subject_alone	26.215	1	26.215	0.764	0.384
n_gender_robot * n_gender_subject	76.743	1	76.743	2.235	0.137
n_gender_robot * subject_alone	65.939	1	65.939	1.921	0.168
n_gender_subject * subject_alone	17.442	1	17.442	0.508	0.477
n_hand_shake * n_gender_robot * n_gender_subject	52.432	1	52.432	1.527	0.218
n_hand_shake * n_gender_robot * subject_alone	37.703	1	37.703	1.098	0.296
n_hand_shake * n_gender_subject * subject_alone	3.987	1	3.987	0.116	0.734
n_gender_robot * n_gender_subject * subject_alone	40.783	1	40.783	1.188	0.278
n_hand_shake * n_gender_robot * n_gender_subject * subject_alone	4.298	1	4.298	0.125	0.724
Error	5115.322	149	34.331		
Total	84582	165			
Corrected Total	6123.794	164			

a R Squared = 165 (Adjusted R Squared = .081)

Tests of Between-Subjects Effects

Dependent Variable:engagement

Source	Squares	df	Mean Square	F	Sig
Corrected Model	810 509^a	7	115.787	3 451	0.002
Intercept	53186 526	1	53186.526	1585 331	0
n_hand_shake	23.993	1	23 993	0 715	0.399
n_gender_robot	1 143	1	1.143	0 034	0.854
n_gender_subject	15.122	1	15.122	0 451	0 503
n_hand_shake * n_gender_robot	287 222	1	287 222	8.561	0 004
n_hand_shake * n_gender_subject	82 217	1	82.217	2.451	0.119
n_gender_robot * n_gender_subject	86.015	1	86 015	2.564	0 111
n_hand_shake * n_gender_robot * n_gender_subject	57.288	1	57 288	1 708	0 193
Error	5367.866	160	33 549		
Total	86569	168			
Corrected Total	6178 375	167			

a R Squared = 131 (Adjusted R Squared = .093)

Tests of Between-Subjects Effects

Dependent Variable:happiness

Source	Squares	df	Mean Square	F	Sig
Corrected Model	2982 689^a	15	198.846	0.736	0.744
Intercept	631632.131	1	631632.131	2337 465	0
n_hand_shake	163.056	1	163 056	0.603	0 439
n_gender_robot	56 885	1	56 885	0.211	0.647
n_gender_subject	328 821	1	328.821	1 217	0.272
subject_alone	366 817	1	366 817	1 357	0.246
n_hand_shake * n_gender_robot	173 523	1	173.523	0.642	0 425
n_hand_shake * n_gender_subject	168 746	1	168 746	0.624	0.431
n_hand_shake * subject_alone	25.242	1	25 242	0.093	0 76
n_gender_robot * n_gender_subject	96 206	1	96 206	0.356	0 552
n_gender_robot * subject_alone	7.743	1	7 743	0 029	0 866
n_gender_subject * subject_alone	363.378	1	363.378	1.345	0 248
n_hand_shake * n_gender_robot * n_gender_subject	425.363	1	425.363	1.574	0.212
n_hand_shake * n_gender_robot * subject_alone	263.089	1	263 089	0.974	0.326
n_hand_shake * n_gender_subject * subject_alone	108 224	1	108 224	0 401	0 528
n_gender_robot * n_gender_subject * subject_alone	82 636	1	82.636	0.306	0.581
n_hand_shake * n_gender_robot * n_gender_subject * subject_alone	12 867	1	12.867	0 048	0.828
Error	32696.741	121	270 221		
Total	1 28E+06	137			
Corrected Total	35679.431	136			

a R Squared = .084 (Adjusted R Squared = - 030)

Tests of Between-Subjects Effects

Dependent Variable happiness

Source	Squares	df	Mean Square	F	Sig
Corrected Model	1599.630^a	7	228.519	0 882	0 522
Intercept	833665.862	1	833665 862	3219.105	0
n_hand_shake	8 496	1	8.496	0 033	0.857
n_gender_robot	2.314	1	2 314	0.009	0 925
n_gender_subject	469.046	1	469.046	1 811	0.181
n_hand_shake * n_gender_robot	158 412	1	158 412	0.612	0.436
n_hand_shake * n_gender_subject	206.7	1	206.7	0 798	0.373
n_gender_robot * n_gender_subject	1 249	1	1.249	0 005	0 945
n_hand_shake * n_gender_robot * n_gender_subject	221 048	1	221.048	0.854	0.357
Error	34184 62	132	258.974		
Total	1.31E+06	140			
Corrected Total	35784.25	139			

a R Squared = .045 (Adjusted R Squared = - 006)

Tests of Between-Subjects Effects

Dependent Variable:time spent on questionnaire

Source	Squares	df	Mean Square	F	Sig.
Corrected Model	4.69E+11	15	3.13E+10	1.143	0.322
Intercept	1 73E+13	1	1.73E+13	632 342	0
n_hand_shake	9 08E+09	1	9.08E+09	0 332	0.565
n_gender_robot	6.00E+10	1	6.00E+10	2.193	0.14
n_gender_subject	2.11E+10	1	2.11E+10	0.772	0.381
subject_alone	5.04E+10	1	5.04E+10	1.841	0.176
n_hand_shake * n_gender_robot	6.50E+10	1	6.50E+10	2.377	0.125
n_hand_shake * n_gender_subject	3 81E+10	1	3 81E+10	1.392	0 24
n_hand_shake * subject_alone	7.92E+08	1	7 92E+08	0.029	0.865
n_gender_robot * n_gender_subject	1 43E+09	1	1.43E+09	0 052	0.82
n_gender_robot * subject_alone	2.91E+08	1	2.91E+08	0.011	0.918
n_gender_subject * subject_alone	4.26E+10	1	4.26E+10	1.558	0.214
n_hand_shake * n_gender_robot * n_gender_subject	3.68E+10	1	3.68E+10	1.347	0.247
n_hand_shake * n_gender_robot * subject_alone	2.49E+09	1	2.49E+09	0.091	0.763
n_hand_shake * n_gender_subject * subject_alone	2.69E+09	1	2 69E+09	0.098	0.754
n_gender_robot * n_gender_subject * subject_alone	4.84E+10	1	4.84E+10	1.769	0.185
n_hand_shake * n_gender_robot * n_gender_subject * subject_alone	6.17E+09	1	6.17E+09	0.226	0.635
Error	4.90E+12	179	2.74E+10		
Total	3.79E+13	195			
Corrected Total	5 36E+12	194			
a. R Squared = .087 (Adjusted R Squared = .011)					

Tests of Between-Subjects Effects					
Dependent Variable.time spent on questionnaire					
Source	Squares	df	Mean Square	F	Sig.
Corrected Model	2.33E+11	7	3.33E+10	1 221	0.293
Intercept	2.08E+13	1	2.08E+13	762.422	0
n_hand_shake	7.92E+09	1	7.92E+09	0.29	0.591
n_gender_robot	1.13E+11	1	1.13E+11	4.154	0.043
n_gender_subject	6.63E+10	1	6.63E+10	2.432	0.121
n_hand_shake * n_gender_robot	6 77E+10	1	6.77E+10	2.484	0.117
n_hand_shake * n_gender_subject	6 55E+10	1	6.55E+10	2.403	0.123
n_gender_robot * n_gender_subject	1.08E+08	1	1.08E+08	0.004	0.95
n_hand_shake * n_gender_robot * n_gender_subject	3.26E+10	1	3 26E+10	1.194	0.276
Error	5.18E+12	190	2.73E+10		
Total	3.87E+13	198			
Corrected Total	5.41E+12	197			
a. R Squared = .043 (Adjusted R Squared = .008)					

Tests of Between-Subjects Effects					
Dependent Variable questions answered					
Source	Squares	df	Mean Square	F	Sig
Corrected Model	8561 329ª	15	570.755	1.252	0.238
Intercept	420467.7	1	420467 7	922.096	0
n_hand_shake	200.819	1	200.819	0.44	0.508
n_gender_robot	623 031	1	623.031	1 366	0.244
n_gender_subject	44.708	1	44 708	0.098	0.755
subject_alone	1702 379	1	1702.379	3.733	0.055
n_hand_shake * n_gender_robot	338.329	1	338.329	0.742	0 39
n_hand_shake * n_gender_subject	142 25	1	142 25	0.312	0 577
n_hand_shake * subject_alone	763 428	1	763.428	1 674	0.197
n_gender_robot * n_gender_subject	234.481	1	234 481	0.514	0.474
n_gender_robot * subject_alone	258 079	1	258.079	0.566	0.453
n_gender_subject * subject_alone	59.322	1	59 322	0.13	0.719
n_hand_shake * n_gender_robot * n_gender_subject	8.779	1	8 779	0.019	0.89
n_hand_shake * n_gender_robot * subject_alone	6 286	1	6 286	0.014	0 907
n_hand_shake * n_gender_subject * subject_alone	9.408	1	9.408	0.021	0.886
n_gender_robot * n_gender_subject * subject_alone	259.103	1	259.103	0 568	0.452
n_hand_shake * n_gender_robot * n_gender_subject * subject_alone	132.904	1	132.904	0.291	0.59
Error	81622 466	179	455.991		
Total	883792	195			
Corrected Total	90183.795	194			

a R Squared = 095 (Adjusted R Squared = 019)

Tests of Between-Subjects Effects

Dependent Variable.questions answered

Source	Squares	df	Mean Square	F	Sig.
Corrected Model	2326 794[a]	7	332 399	0.716	0 659
Intercept	505993 821	1	505993.821	1089.664	0
n_hand_shake	312 419	1	312 419	0.673	0.413
n_gender_robot	1605 41	1	1605 41	3 457	0.065
n_gender_subject	0 395	1	0.395	0 001	0 977
n_hand_shake * n_gender_robot	162 997	1	162.997	0 351	0 554
n_hand_shake * n_gender_subject	175 04	1	175 04	0 377	0 54
n_gender_robot * n_gender_subject	142 101	1	142.101	0.306	0 581
n_hand_shake * n_gender_robot * n_gender_subject	22.145	1	22.145	0 048	0 827
Error	88227 959	190	464 358		
Total	900667	198			
Corrected Total	90554.753	197			

a R Squared = 026 (Adjusted R Squared = - 010)

Distance

Tests of Between-Subjects Effects

Dependent Variable·gave donation

Source	Squares	df	Mean Square	F	Sig
Corrected Model	2 696[a]	7	0.385	2 674	0.014
Intercept	44 2	1	44 2	306 82	0
n_distance	0.192	1	0.192	1 335	0.25
n_gender_subject	1.784	1	1.784	12.382	0.001
subject_alone	0.016	1	0 016	0 114	0.736
n_distance * n_gender_subject	0 192	1	0 192	1.335	0 25
n_distance * subject_alone	0 099	1	0.099	0 691	0.408
n_gender_subject * subject_alone	0 576	1	0.576	3 999	0.048
n_distance * n_gender_subject * subject_alone	0 099	1	0.099	0 691	0.408
Error	14 982	104	0.144		
Total	90	112			
Corrected Total	17.679	111			

a R Squared = .153 (Adjusted R Squared = .095)

Tests of Between-Subjects Effects

Dependent Variable:gave donation

Source	Squares	df	Mean Square	F	Sig.
Corrected Model	1 515[a]	3	0 505	3.398	0 02
Intercept	48 075	1	48 075	323 442	0
n_gender_subject	1 248	1	1 248	8.399	0 005
n_distance	0 372	1	0.372	2 502	0.117
n_gender_subject * n_distance	0 399	1	0.399	2 686	0 104
Error	16 201	109	0.149		
Total	91	113			
Corrected Total	17 717	112			

a R Squared = 086 (Adjusted R Squared = 060)

Tests of Between-Subjects Effects

Dependent Variable:donation

Source	Squares	df	Mean Square	F	Sig.
Corrected Model	30.591[a]	7	4.37	0.968	0.458
Intercept	668 772	1	668.772	148.181	0
n_distance	1.667	1	1.667	0 369	0 545
n_gender_subject	26.49	1	26.49	5.869	0.017
subject_alone	0 837	1	0.837	0 186	0 668
n_distance * n_gender_subject	4 182	1	4.182	0 927	0 338
n_distance * subject_alone	1.02	1	1.02	0.226	0 635
n_gender_subject * subject_alone	4 23	1	4 23	0 937	0 335

n_distance * n_gender_subject * subject_alone	0.066	1	0.066	0.015	0.904
Error	469.373	104	4.513		
Total	1496	112			
Corrected Total	499.964	111			
a. R Squared = .061 (Adjusted R Squared = -.002)					

Tests of Between-Subjects Effects					
Dependent Variable:donation					
Source	Squares	df	Mean Square	F	Sig
Corrected Model	25.301[a]	3	8.434	1.921	0.13
Intercept	724.466	1	724.466	165.01	0
n_gender_subject	23.615	1	23.615	5.379	0.022
n_distance	0.754	1	0.754	0.172	0.679
n_gender_subject * n_distance	5.47	1	5.47	1.246	0.267
Error	478.557	109	4.39		
Total	1497	113			
Corrected Total	503.858	112			
a. R Squared = .050 (Adjusted R Squared = .024)					

Tests of Between-Subjects Effects					
Dependent Variable:credibility					
Source	Squares	df	Mean Square	F	Sig
Corrected Model	1087.842[a]	7	155.406	0.928	0.489
Intercept	428839.042	1	428839.042	2559.578	0
n_distance	0.763	1	0.763	0.005	0.946
n_gender_subject	153.307	1	153.307	0.915	0.341
subject_alone	52.657	1	52.657	0.314	0.576
n_distance * n_gender_subject	765.869	1	765.869	4.571	0.035
n_distance * subject_alone	1.426	1	1.426	0.009	0.927
n_gender_subject * subject_alone	5.047	1	5.047	0.03	0.863
n_distance * n_gender_subject * subject_alone	72.634	1	72.634	0.434	0.512
Error	15581.485	93	167.543		
Total	613498	101			
Corrected Total	16669.327	100			
a. R Squared = .065 (Adjusted R Squared = -.005)					

Tests of Between-Subjects Effects					
Dependent Variable:credibility					
Source	Squares	df	Mean Square	F	Sig
Corrected Model	916.100[a]	3	305.367	1.895	0.135
Intercept	457632.552	1	457632.552	2840.203	0
n_gender_subject	176.015	1	176.015	1.092	0.299
n_distance	3.161	1	3.161	0.02	0.889
n_gender_subject * n_distance	848.396	1	848.396	5.265	0.024
Error	15790.419	98	161.127		
Total	620387	102			
Corrected Total	16706.52	101			
a. R Squared = .055 (Adjusted R Squared = .026)					

Tests of Between-Subjects Effects					
Dependent Variable:credibility - safety					
Source	Squares	df	Mean Square	F	Sig.
Corrected Model	264.442[a]	7	37.777	1.411	0.209
Intercept	62210.65	1	62210.65	2323.866	0
n_distance	47.194	1	47.194	1.763	0.187
n_gender_subject	0.248	1	0.248	0.009	0.923
subject_alone	27.763	1	27.763	1.037	0.311
n_distance * n_gender_subject	99.325	1	99.325	3.71	0.057
n_distance * subject_alone	5.333	1	5.333	0.199	0.656
n_gender_subject * subject_alone	13.73	1	13.73	0.513	0.476
n_distance * n_gender_subject * subject_alone	7.163	1	7.163	0.268	0.606
Error	2623.492	98	26.77		
Total	90245	106			

Corrected Total	2887.934	105			

a. R Squared = .092 (Adjusted R Squared = .027)

Tests of Between-Subjects Effects

Dependent Variable:credibility - safety

Source	Squares	df	Mean Square	F	Sig.
Corrected Model	214.381[a]	3	71.46	2.713	0.049
Intercept	65416.309	1	65416.309	2483.757	0
n_gender_subject	0.057	1	0.057	0.002	0.963
n_distance	50.806	1	50.806	1.929	0.168
n_gender_subject * n_distance	101.14	1	101.14	3.84	0.053
Error	2712.778	103	26.338		
Total	91470	107			
Corrected Total	2927.159	106			

a. R Squared = .073 (Adjusted R Squared = .046)

Tests of Between-Subjects Effects

Dependent Variable credibility - qualification

Source	Squares	df	Mean Square	F	Sig.
Corrected Model	315.922[a]	7	45.132	1.13	0.351
Intercept	56113.235	1	56113.235	1404.989	0
n_distance	46.363	1	46.363	1.161	0.284
n_gender_subject	103.159	1	103.159	2.583	0.111
subject_alone	7.588	1	7.588	0.19	0.664
n_distance * n_gender_subject	132.579	1	132.579	3.32	0.072
n_distance * subject_alone	0.93	1	0.93	0.023	0.879
n_gender_subject * subject_alone	18.24	1	18.24	0.457	0.501
n_distance * n_gender_subject * subject_alone	25.739	1	25.739	0.644	0.424
Error	3874.04	97	39.939		
Total	80627	105			
Corrected Total	4189.962	104			

a. R Squared = .075 (Adjusted R Squared = .009)

Tests of Between-Subjects Effects

Dependent Variable:credibility - qualification

Source	Squares	df	Mean Square	F	Sig
Corrected Model	195.697[a]	3	65.232	1.662	0.18
Intercept	59332.407	1	59332.407	1511.731	0
n_gender_subject	90.126	1	90.126	2.296	0.133
n_distance	45.667	1	45.667	1.164	0.283
n_gender_subject * n_distance	163.371	1	163.371	4.163	0.044
Error	4003.294	102	39.248		
Total	81527	106			
Corrected Total	4198.991	105			

a. R Squared = .047 (Adjusted R Squared = .019)

Tests of Between-Subjects Effects

Dependent Variable:credibility - dynamism

Source	Squares	df	Mean Square	F	Sig
Corrected Model	185.973[a]	7	26.568	0.938	0.481
Intercept	32587.364	1	32587.364	1150.437	0
n_distance	0.504	1	0.504	0.018	0.894
n_gender_subject	13.454	1	13.454	0.475	0.492
subject_alone	50.643	1	50.643	1.788	0.184
n_distance * n_gender_subject	55.305	1	55.305	1.952	0.166
n_distance * subject_alone	27.768	1	27.768	0.98	0.325
n_gender_subject * subject_alone	56.428	1	56.428	1.992	0.161
n_distance * n_gender_subject * subject_alone	49.135	1	49.135	1.735	0.191
Error	2634.324	93	28.326		
Total	48375	101			
Corrected Total	2820.297	100			

a. R Squared = .066 (Adjusted R Squared = -.004)

Tests of Between-Subjects Effects

Dependent Variable:credibility - dynamism

Source	Squares	df	Mean Square	F	Sig.
Corrected Model	76.199[a]	3	25.4	0.904	0.442
Intercept	34853.88	1	34853.88	1240.046	0
n_gender_subject	20.054	1	20.054	0.714	0.4
n_distance	0.095	1	0.095	0.003	0.954
n_gender_subject * n_distance	70.919	1	70.919	2.523	0.115
Error	2754.478	98	28.107		
Total	48699	102			
Corrected Total	2830.676	101			

a. R Squared = .027 (Adjusted R Squared = -.003)

Tests of Between-Subjects Effects

Dependent Variable:trust

Source	Squares	df	Mean Square	F	Sig
Corrected Model	1465.777[a]	7	209.397	1.108	0.366
Intercept	432010.692	1	432010.692	2285.2	0
n_distance	374.555	1	374.555	1.981	0.163
n_gender_subject	60.061	1	60.061	0.318	0.574
subject_alone	88.113	1	88.113	0.466	0.497
n_distance * n_gender_subject	388.828	1	388.828	2.057	0.155
n_distance * subject_alone	3.904	1	3.904	0.021	0.886
n_gender_subject * subject_alone	2.553	1	2.553	0.014	0.908
n_distance * n_gender_subject * subject_alone	14.515	1	14.515	0.077	0.782
Error	16447.107	87	189.047		
Total	605920	95			
Corrected Total	17912.884	94			

a. R Squared = .082 (Adjusted R Squared = .008)

Tests of Between-Subjects Effects

Dependent Variable:trust

Source	Squares	df	Mean Square	F	Sig.
Corrected Model	1233.753[a]	3	411.251	2.197	0.094
Intercept	455745.741	1	455745.741	2435.221	0
n_gender_subject	31.235	1	31.235	0.167	0.684
n_distance	486.205	1	486.205	2.598	0.11
n_gender_subject * n_distance	326.31	1	326.31	1.744	0.19
Error	17217.58	92	187.148		
Total	616324	96			
Corrected Total	18451.333	95			

a. R Squared = .067 (Adjusted R Squared = .036)

Tests of Between-Subjects Effects

Dependent Variable.engagement

Source	Squares	df	Mean Square	F	Sig.
Corrected Model	227.406[a]	7	32.487	1.126	0.355
Intercept	36586.389	1	36586.389	1267.825	0
n_distance	35.752	1	35.752	1.239	0.269
n_gender_subject	36.24	1	36.24	1.256	0.266
subject_alone	0.546	1	0.546	0.019	0.891
n_distance * n_gender_subject	67.792	1	67.792	2.349	0.129
n_distance * subject_alone	86.471	1	86.471	2.996	0.087
n_gender_subject * subject_alone	1.097	1	1.097	0.038	0.846
n_distance * n_gender_subject * subject_alone	8.809	1	8.809	0.305	0.582
Error	2481.754	86	28.858		
Total	51565	94			
Corrected Total	2709.16	93			

a. R Squared = .084 (Adjusted R Squared = .009)

Tests of Between-Subjects Effects

Dependent Variable.engagement

Source	Squares	df	Mean Square	F	Sig

Corrected Model	129 074[a]	3	43 025	1 507	0 218
Intercept	38181.332	1	38181.332	1337.603	0
n_gender_subject	33.858	1	33.858	1 186	0.279
n_distance	22.174	1	22.174	0 777	0.38
n_gender_subject * n_distance	81.693	1	81 693	2 862	0 094
Error	2597 558	91	28 545		
Total	52294	95			
Corrected Total	2726 632	94			

a R Squared = 047 (Adjusted R Squared = .016)

Tests of Between-Subjects Effects

Dependent Variable happiness

Source	Squares	df	Mean Square	F	Sig
Corrected Model	1545.627[a]	7	220.804	0 751	0 629
Intercept	569043.416	1	569043 416	1936 642	0
n_distance	195 553	1	195.553	0 666	0 417
n_gender_subject	1079.881	1	1079.881	3 675	0.059
subject_alone	16 044	1	16.044	0 055	0 816
n_distance * n_gender_subject	752 5	1	752.5	2 561	0.114
n_distance * subject_alone	0.897	1	0 897	0 003	0 956
n_gender_subject * subject_alone	35 646	1	35.646	0 121	0 729
n_distance * n_gender_subject * subject_alone	80 843	1	80 843	0 275	0 601
Error	21449.583	73	293.83		
Total	771028	81			
Corrected Total	22995 21	80			

a. R Squared = 067 (Adjusted R Squared = - 022)

Tests of Between-Subjects Effects

Dependent Variable.happiness

Source	Squares	df	Mean Square	F	Sig
Corrected Model	1427 998[a]	3	475.999	1.717	0 17
Intercept	592720 562	1	592720.562	2137.522	0
n_gender_subject	1081 436	1	1081.436	3.9	0 052
n_distance	221 559	1	221 559	0.799	0.374
n_gender_subject * n_distance	750 319	1	750 319	2 706	0 104
Error	21628 88	78	277.293		
Total	781844	82			
Corrected Total	23056 878	81			

a R Squared = 062 (Adjusted R Squared = .026)

Tests of Between-Subjects Effects

Dependent Variable.time spent on questionnaire

Source	Squares	df	Mean Square	F	Sig
Corrected Model	1.32E+11	7	1.89E+10	0 57	0.779
Intercept	1 39E+13	1	1.39E+13	418 547	0
n_distance	6.70E+09	1	6 70E+09	0.202	0.654
n_gender_subject	5 65E+10	1	5 65E+10	1.7	0.195
subject_alone	8 46E+09	1	8 46E+09	0.254	0.615
n_distance * n_gender_subject	5 87E+09	1	5 87E+09	0.177	0.675
n_distance * subject_alone	5 51E+09	1	5 51E+09	0.166	0 685
n_gender_subject * subject_alone	3 26E+10	1	3.26E+10	0 981	0 324
n_distance * n_gender_subject * subject_alone	5.76E+09	1	5 76E+09	0.173	0.678
Error	3 46E+12	104	3.32E+10		
Total	2 29E+13	112			
Corrected Total	3.59E+12	111			

a. R Squared = .037 (Adjusted R Squared = -.028)

Tests of Between-Subjects Effects

Dependent Variable.time spent on questionnaire

Source	Squares	df	Mean Square	F	Sig
Corrected Model	6.24E+10	3	2.08E+10	0 643	0.589
Intercept	1.45E+13	1	1.45E+13	449.424	0
n_gender_subject	4.94E+10	1	4.94E+10	1 526	0 219

n_distance	8.62E+09	1	8.62E+09	0.267	0.607
n_gender_subject * n_distance	5.92E+09	1	5.92E+09	0.183	0.67
Error	3.53E+12	109	3.23E+10		
Total	2.31E+13	113			
Corrected Total	3.59E+12	112			

a R Squared = .017 (Adjusted R Squared = -.010)

Tests of Between-Subjects Effects

Dependent Variable: questions answered

Source	Squares	df	Mean Square	F	Sig.
Corrected Model	4591.954[a]	7	655.993	1.508	0.173
Intercept	349961.543	1	349961.543	804.601	0
n_distance	875.331	1	875.331	2.012	0.159
n_gender_subject	194.571	1	194.571	0.447	0.505
subject_alone	435.691	1	435.691	1.002	0.319
n_distance * n_gender_subject	50.488	1	50.488	0.116	0.734
n_distance * subject_alone	821.799	1	821.799	1.889	0.172
n_gender_subject * subject_alone	111.267	1	111.267	0.256	0.614
n_distance * n_gender_subject * subject_alone	110.012	1	110.012	0.253	0.616
Error	45234.823	104	434.95		
Total	509219	112			
Corrected Total	49826.777	111			

a R Squared = .092 (Adjusted R Squared = .031)

Tests of Between-Subjects Effects

Dependent Variable: questions answered

Source	Squares	df	Mean Square	F	Sig.
Corrected Model	2000.074[a]	3	666.691	1.516	0.215
Intercept	362095.777	1	362095.777	823.191	0
n_gender_subject	250.552	1	250.552	0.57	0.452
n_distance	1421.175	1	1421.175	3.231	0.075
n_gender_subject * n_distance	99.52	1	99.52	0.226	0.635
Error	47945.661	109	439.868		
Total	514844	113			
Corrected Total	49945.735	112			

a R Squared = .040 (Adjusted R Squared = .014)

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