Selinus University of Sciences and Literature

Department of Computer Science

Human and robot relationship behavior

This study shows human and robot relations and how robot can and have effect on mordent human life

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Master of Science in Computer Science

Artificial Intelligence

Robots Intelligent

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Research Advisor: Dr. Francisco Bulnes PhD

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ABSTRACT OF THE THESIS

In ore mordent life there is no doubt that robot is part of ore life be integrated into mainstream civilization, and as they do the amount of contact and the number of interactions they have with humans will develop at a similar rate. These interactions present a new set of issues for robot makers and programmers. What is the best way for robots to communicate with humans? This study tested the importance of gestures in creating useful human-robot interactions. Conducted using the PR2, this study explored the role of gestures in two primary kinds of communications: the robot communicating a need (low power) to an unsuspecting human, and a robot building trust with a human partner on an instruction reading task. we predicted that gestures would guide further effective interactions than the non-gesture controls. We also used this chance to examine a large unsearched area in proxemics: the idea that free, "bouncing" arms led to lower attributions of dominance than stiff, fixed arms. Our research highlighted the importance of gestures in communication, particularly amongst people who tended to look at robots as more than machines.

Acknowledgements

First and foremost, this research would not have been possible without the support of my family.

This Research Paper it is beast On early research which have been done by Willow Garage research team I have done an update on human and robot relations and robot behavior by my own privet research methods.

My passion for making robots and understand the robot behavior make it passable for me to come with this research pepper.

Amar Yasir M

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Preface

There's a question In many people's minds dos robots ever hope to be human? the answer is indeed is not in a literal sense, hover in a behavioral sense; can a robot ever act as if it were human? What would be the implications of such a mechanism that behaved like a human? The idea of robots that behave like a human is actually not strange in the slightest. In popular science fiction, we can find examples of robots that are almost human. The Terminator (1984), Robocop (1987), WALL-E (2008), and Big Hero 6 (2014) ......we can find in our culture have for long adopted the idea of robots that were more than just metal, electronics parts, and wires. as we can find from the examples above were all social personalities existing in and interacting with the social worlds around them.

In Modern robots, however, can demand nowhere near the level of sophistication that any of these fictional robots can. The large nuances of human social interactions are still mainly mysteries to psychologists and sociologists alike, so it is not surprising that there has been limited work achieved in implementing human-like social behavior in robots it is logic. It's like evolutionary pressures of living in social environments that may have led to the evolution of our own social behaviors, robots are now increasingly finding themselves in social situations, which many are ill-equipped to handle. A magnificent example is the robot waitress is an innovative useful robot that can act as an interactive(waiter) assistant for any service area. the robot waitress can carry out reception duties option duties such as food and drinks, and it can deliver food and drink create an interactive shopping experience and provide consultative and informative explanations it is a unique idea in our modern world, hover the robot waiter cannot act as human do in many ways, yes it can do some time peter job than a waiter. the robot waiter story is not unique among robots in our modern life today. In fact, robot culture is growing more mainstream every day, but they are bound to face numerous hardships and hurdles as they become open for commercial use that needs an increasing amount of human interaction. Obviously, robots like the robot vacuum cleaner will continue to be successful even though they hold no social skills, but as robots take on more complex jobs, they will inevitably need to be able to interact with people in a social environment. we humans need to be able to communicate to robots easily what they need the robot to do and feel confident in the fact that the robot will do it.

Moreover, the robot needs to communicate its needs and purposes with people. As a large percentage of what we communicate is nonverbal, easily attaching a voice to the robot with some crucial prerecorded phrases will not be enough for real interaction. The robot must be provided with social gestures.

This is where our work appears. This study consists of experiments to test if giving robots gestures both facilitates a robot in sharing its needs and purposes with humans and helps instill trust in humans that robots follow their instructions when they share them with the robot. We will also be taking advantage of the opportunity to search for a new factor that could affect proxemics distance between us humans and robots: the robot's arms are rigidly held in a set position or a looser position, more able to move slightly with the robot's mobility. We are hoping that the evidence gained here will help pave the way for future generations of social robots.

1 Background

1.1 Gestures Facilitating Communication

It became more clearly distinguishes robots from other machines in the world is that people are generally more apt to treat these machines as people than they would a typical automobile it is a very interesting thing, like washing machine, or even personal computer. Many are frequently treated like animal pets, and sometimes even as children. Take, for instance, the example of Vector made by(Anki 2019) Vector is a companion made to hang out and help out. Vector is Powered by ai & advanced robotics, his software makes it look alive with personality & engaged by sight, touch, and sound.

Vector is voice-activated and of course, answers many questions, it can take photos for you, tell you time for dinner, it can show you the weather & temperature, and more. it allowed a human to make difficult interpretations of the social scenarios and choose the appropriate response. The results showed that when naïve humans (that is to say humans without prior experience with robots) interacted with Vector, they overwhelmingly treated it as if it were a real living creature. The humans (especially young kids/children) displayed a wide variety of emotions and feelings to Vector based on the different behaviors it displayed. Some would tease Vector and many would show great compassion treating it as they would a puppy. Behaviors like this do not manifest for interactions with more traditional machines, and it seems to be the nonverbal communication that brings about these behaviors.

It appears that, widely, robots get an automatic upgrade from devices when people meet them. it may be this is the result of generations of science fiction movies explaining to us what we hope one-day robots could be; at any time, it seems immediately apparent that we humans attend to approach robots with very different expectations than they approach computers or washing machines. Usually, the robots fail to meet the lofty expectations of the human and the expectation drops quickly (as was seen with the robot waiter),

However, if, as was the case with Vector, the robot can socially engage with the human, hypothesize people will continue to place these machines on a pedestal over all others. The key lies in the robot/machine’s ability to be perceived as a social character, rather than a functional target. however, because puppies are so strongly ingrained in our lives and have been for thousands of years, canine gestures also prove to elicit social acknowledgments from humans. The same was true in the case of this robot, especially when humans implied primed with canine images; they overwhelmingly responded to the robot's gestures with behaviors typically demonstrated towards dogs. The people would pet or stroke the robot- behaviors surely not common in other human-machine relationships. Some humans even went as far as appraising the robot’s intelligence as high based merely on these interactions, suggesting that maybe nonverbal behavior is the key to studies of intelligence.

The concept that nonverbal behavior can begin to perceptions of intelligence is a bit murky, mainly because the idea of intelligence itself is a bit murky, left largely to the idea of the person ascribing the intelligence. Intelligence is a wide, vague term expressing many different things to many different people. Surely, proper use of social cues does not imply mathematical prowess (though perhaps merely being a robot does); what it does seem to suggest is a specific level of social intelligence, which in and of itself is a problematic term, but it is clearly closer and easier for us to work with. Social intelligence is known by many nicknames including social competence, emotional intelligence, and social ability to mention a few. For this paper, we will apply the word social competence to help have a better distinction from the messier understanding of intelligence. The relation between nonverbal behavior and social competence is fully documented across many studies for human-human interactions. Feldman, Phillipot, and Custrini (1991) reviewed the results of several of these studies recording that there was a clear positive relationship between social competency and the use of nonverbal behavior skills. In other words, people who were evaluated to have high social competence also demonstrated a high level of nonverbal behavior skills. The researchers did not go as far as to imply a direction of the correlation or suggest causation among the variables. This evidence shows the reports by the participants of the Shibata et al. (1997) study that the robot performing social behavior was "intelligent." Perhaps "intelligent" was not the most perfect word to describe it; as we have explained previously social competence seems to be more applicable for this condition. However, not like Feldman-et al, Shibata et al. can discuss the relationship in a causal sense. However because the robot has no intrinsic social competence, it is difficult to say that the social competence caused the nonverbal behavior. Obviously in this case the nonverbal behavior lets the participants ascribe them with social competency, a key point this research aims to prove as well.

1.2 Nonverbal Behavior and Dominance

As we find out, social competence is not the only skill that we can ascribe to objects given the object's nonverbal behavior. Consider classic cartoons and 3D animation films. Alike to robots, classic cartoons and other animated characters simply loosely represent humans or other autonomous agents in physical form, still, when done well, very powerful feelings and ideas can form around these characters. The reason for this is because these characters express to us on a nonverbal behavior level. As Johnston and Thomas (1995) wrote in their landmark book, Illusions of Life: Disney Animation, animators try to create long, rich personalities for their characters without explicitly verbalizing those personalities. That means their personalities must be communicated through their dress, their mannerisms, and their gestures. The idea of conveying dominance and power, for instance, always seems to be associated with a quiet stillness or stiffness. Johnston and Thomas applied the example that it would be a significant break of character if the wicked witch, while slowly & carefully walking down the dungeon stairs, falls and goes tumbling down to the ground. Stumbling and falling portray weakness; she would clearly not be in control of her environment in that scenario. There is no reason why these animation principles cannot be applied to robots to try to convey similar ideas in our studies and as robots continue to grow more social in the future.

So, it is easy to say that if we apply these animation techniques to our robots we can convey these deep social messages, and quite another to prove that these messages are indeed successfully conveyed. Merely asking participants to report their perceptions might be adequate for some standard of certainty, but we aim to have harder metrics not tied to subjective participant perceptions. In order to do this, we turn our attention to the field of proxemics, the study of personal space. In 1966, Edward T. Hall published his findings on proxemics in which he claimed that we all have personal bubbles that get smaller and smaller the more familiar we are with people. For instance, our most intimate of companions we permit to enter our most intimate circle, whereas strangers are kept at the furthest distance from us. If we take this notion a step further we can say that we permit people with whom we are more comfortable to be closer to us than those we are not. This does not give us a perfectly clean metric for determining whether messages have been successfully conveyed, but it will give us a better idea of what participants actually think. For instance, dominant personalities are often perceived as intimidating, so we are not comfortable around them and therefore try to keep them at greater distances from us. Using this idea we can test if one posture or stance is more submissive than another.

Similar studies have been conducted already testing a wide range of parameters that affect proxemics between humans and robots. Research done by Takayama & Pantofaru (2009) examined to see what role eye touch and the locus of control (human approaches robot VS robot approaches human) performed in proxemics distance. They did find that eye contact played a role in the distance. Strangely, it only performed a role with women, however. Women managed to keep the robots at a further distance when the robots were looking at them than when they were not. Also strangely, they found the locus of control had no significant bearing on distance. They concluded noting that these differences needed to be investigated more. Another research by Visser &Van Oosterhaut (2008) discovered that like the findings of Takayama and Pantofaru, people mostly adhere to related standards and rules with robots as they do among humans. They also found that women displayed further distances than men. They did test for height disparity but were unable to find any conclusive trends. The fact that these two studies both found larger distances with women as opposed to men is very interesting and something that this study will hope to explore further.

1.3 Gestures and Trust

It is not just enough for people to be comfortable around robots; all machines require a function (a task for which they were designed to complete) to be useful for users. Since we already know that people tend not to interact with robots as they interact with other machines, we would not expect task assignment for an autonomous robot to work the way task assignment works for a microwave or washing machine. No doubt the long-term goal for robots is for them to process voice commands from users, which seems a reasonable goal given similar voice command technology is already deployed in several makes of automobiles. Voice recognition software is inherently unreliable and many times makes mistakes, leading to confusion. If we take a moment however to think about it we may quickly realize that our speech recognition errs frequently as well.

We mishear or misinterpret what people say daily; therefore it is not surprising that our machines struggle with similar issues. We know almost it using subtle cues presented in a pseudo- ritualistic fashion explaining to the instructor that the instructions were received and giving assurance they were understood. So the question then becomes how do we prove to users that robots have understood tasks that are given to them? In other words, we must explore ways that a rudimentary level of trust can be established between humans and machines. What cues are necessary to create a pseudo trust establishment ritual between humans and robots?

Lee and See (2004) described trust as “the attitude that an agent will help achieve an individual’s goals in a state characterized by risk and vulnerability.” This is precisely what we hope to influence with our research. Lee and See moved on to argue that trust is built and evaluated in 3 ways: analogical, analytical, and effective. Analytic trust is built using rational principles and is built up over time. Someone builds trust with someone else if they consistently prove to be trustworthy. This is true and fairly obvious for our interactions, but certainly not all trust is built that way; we can all think of those people we’ve interacted with that instantly gain our trust. In the analogical construction of trust, people use characteristics they observe of the person and the context to decide whether that person is worthy of their trust. They also largely rely on outside sources such as gossip and previous experiences. The effective evaluation of trust does not rely on reason to the extent that the previous two do. Affective relies most heavily on emotion; as trust is betrayed, negative emotions will be associated with the violator and when trust is not abused, it is rewarded with positive emotions. Thus the decision of trust is made by deciding whether they feel the person deserves trust based on the emotions they feel towards the person in question. For this paper, we will need to focus on the analogical construction of trust, as both affective and analytical involve developing a bit richer history between truster and trustee to be effective. We can however most easily manipulate context and robot characteristics in a controlled setting.

There is no doubt that trust will have to play an important role in any kind of interaction between humans and machines. Research by DeVisser, Freedy, Weltman, and Coeyman (2007) highlighted this point in their research including an autonomous targeting method for robotic military stands. Participant trust in the targeting system was primarily affected by cues that suggest the system was not competent to handle targeting on its own. If the machine happened to display low competence, then participants would improve out, but if it happened to display medium level competence, people were more inclined to not interfere, because, the researchers theorized, the level of competence could not easily be determined. They also noted that the first impressions participants had with the autonomous system greatly affected their levels of trust in the system. For example, if participants were originally tested with a high competence system, and then tested with a low competence system, their previous experience with a high competence system seemed to lead them to not interfere with the low competence system. This provides us with keen insight into critical moments when trust can be fostered or lost, but it does not, unfortunately, give us an idea of what kind of ideas can be used for larger domestic applications.

A panel of human-robot interaction specialists (Bruemmer et al. 2004) shared their thoughts on what they believed would be the best way to build trust in robots. Their views came from a wide range of disciplines, and not all the approaches applied to this research, but several provided some interesting ideas that proved to be valuable in designing the present study. Donald Norman thinks the key to getting people to trust robots lies in the robot's ability to be "human;" to own emotion, personality, and rich interactions with humans. This idea is related to the ideas of the Disney animators Thomas and Johnston, when they were describing how to create "life" through animation, and making interactions more comfortable certainly seems an easy way to build trust. In fact, a different panelist, William Smart, explains that the key lies in giving social cues indicating to others what the robot's internal state is. Many of this theorizing came from the earlier work he did with the robot waiter robot discussed earlier. While the concepts of Smart and Norman seem to fundamentally get to the core idea of making interactions richer, the ideas that Smart proposes at least in the short period are higher feasible because creating a robot “human” as Norman proposes is an amazingly lofty idea, that likely will not see fruition for several decades. The views presented by these two researchers are the most applicable to this research because the primary variable we are trying to manipulate is the participant perception. Building off these ideas, we can use human-like gestures and cues to help foster a sense of trust.

This research attempts to bring all of these ideas explained above and test each of them to determine the role that gestures can play in human-robot interaction. The first experiment points to a test to see if gestures can help communicate ideas about the robot's internal states (“needs”). This is accomplished by having the robot try to communicate that it needs help with an unsuspecting participant. The robot will communicate in one of two methods either in using gestures or vocoded voice. The second experiment will carry on the idea of dominance discussed in section 1.2, and rely on proxemics measures to interpret whether or not dominance has been conveyed.

The robot will decrease the participant with either rigid (unmoving) arms, or slightly bouncing arms; first, the robot will approach the participant, then the robot will back up, and the participant will approach the robot. Lastly, we will assess what role gestures can perform in establishing trust. The participant will read a set of instructions to the robot and the robot will either nod or do nothing, and the participant's level of trust will be measured using a questionnaire.

2 Methods

1.1 Materials

Figure 1 the PR2 robot

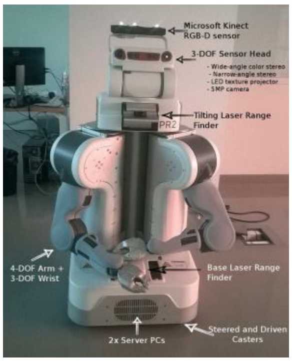


Figure 1.1 PR2 robot with its sensors and hardware.

Back in 2011, the research team used the pr2 robot for their experiment and I find it magnificent to use the same experiment with my own virgin of explaining this experiments, (Figure 1). As we can see the robot has two arm-like actuators and cameras arranged on the head that give the robot an approximately human-like appearance, though clearly distinct enough so as can clearly be identified as a robot. In the event of a malfunction in the autonomous system, the experimenter always had a teleoperated.

controller nearby during all experiments to take control manually if necessary. A remote kill switch was also kept on hand in the unlikely event the robot malfunctioned in a way that could put someone at risk.

2.3 Procedure/Data

They did the experiment in four smaller experiments. For the purposes of early research, they have done, we will only focus on the first three parts of the experiment, as the fourth part was designed and administered by researchers at Willow Garage. Sometimes the Willow Garage study was run before our study and sometimes it was run after, but again since it was a different robotic platform, they believe the pollution will be minimal. Before the study begins, each participant was given a short tour of the facilities and introduced to a few PR2 robots (to ensure that their measured reactions to the robot are not merely reflective of them just marveling at the technology).

2.3.1 Experiment 1: Robot needs help

Figure 2: Robot Gesturing, (left) calibration imitation, (center) waving cord, (right) pointing at plug

Figure 2.1

The first experiment aims to ascertain if a robot that uses gestures can more effectively communicate information regarding a robot's current "internal states" or, in lay terms if gestures can help robots convey to humans what their "needs" are and see if the robot can successfully solicit help from the participants. That is accomplished by holding the participant sit alone next to a PR2 for two minutes while the robot does one of the two experimental behaviors, which will indicate to the participant that the battery is low and requires to be recharged. Some of the participants (n= 6) encountered a robot issuing an explicit verbal command ("Low battery, help me"), and the remainder (n=12) encountered a robot that gestured at the participant by holding out its power plug and pointing to the power outlet (See Figure 2). To begin, the participant enters the room and sits on the cheer at a desk near the robot seemingly engaged in a sensor calibration routine (See figures 3 and 4 for room layout and setup).

Immediately after the participant marks the consent form, a camera starts rolling that will be applied to track eye contact. The experimenter then apologizes for being disorganized and says he need to run and go print another document before the research can proceed. Shortly after the experimenter leaves the room, the

robot will close the calibration imitation and start one of the experimental conditions. After approximately 2 minutes, the experimenter will return with the “missing” document and take the participant to another room to complete the post-experiment 1 questionnaire. A copy of the questionnaire is included on page 31 of the appendix. At times participants were reminded which

Figure 4: Experiment 1 room setup

the robot was the one they had the interaction with. For this experiment, the associate needed to be left alone to reduce diffusion of responsibility and maximize the opportunities that the robot’s actions were perceived as directed towards the participant. The participants’ eye gaze at the robot in the presence of these socially engaging stimuli was measured by using a stopwatch to time how many seconds the participant looked at the robot which is in the video of the communication. We understand that a higher amount of eye gaze follows an attempt by the participant to discern what the robot is trying to convey.

2.3.2 Experiment 2: Proxemics

The aim of the second experiment is to discover out what a comfortable interaction distance is for people and robots, and how different ways the robot appears affect those distances. There have previously been extensive researches on the effects of height on comfortable interaction distance, so for this experiment, we will try to control for that by setting the robot height to approximately 86% of the participant’s height, and focusing our awareness on arm tension (firm or loose). The motivation behind this comes from the idea fixed by Thomas and Johnston (1995) where characters that are stiff and hard are perceived as more dominant than those that are not. Half (n =9) of the participants remained in the firm arms condition and the other half (n = 9) occurred in the loose arm condition. they ran every test twice, once where the robot approached the participants and once

where the participants approached the robot. After the survey was performed for experiment 1, the experimenter leads the participant within a maze of hallways and shows off another operation at Willow that wasn’t introduced in the original tour.

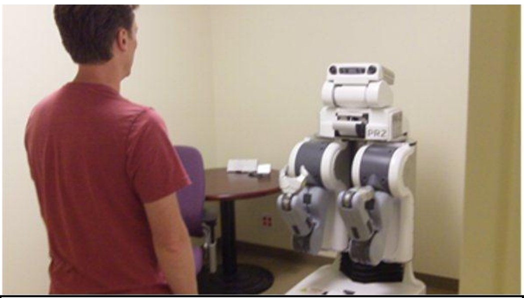


Figure 5: Experiment 2 room setup

Meanwhile, a confederate moves the robot to the location of experiments 2 & 3. The experimenter and participant arrive in the room shortly after the room is set up (See figure 5 for room setup). The experimenter then directs the participant where to stand and explains that the robot will approach him, and when the robot is on edge of a comfortable distance for the participant (i.e. if the robot were to get any closer it would be uncomfortable for the participant), the participant should clearly say stop, and the robot’s progress will be halted. A measurement from the robot’s laser range finder will be taken at that point. The robot then backed up several feet and the participant was told to approach the robot before beginning the third and final experiment. The laser range finder reading was again taken at this point. Data of the laser range finder was connected between conditions (loose and stiff arms), and inside conditions (human approach and robot approach) to see if there were any meaningful correlations. The experiment immediately proceeded into experiment 3 with no interference from the experimenter.

2.3.3 Experiment 3: Head nodding

Similar the Experiment nr 1, Experiment nr 3 involved robots applying human-like social gestures, and in this example, the gesture was head nodding while a participant read instructions. At the beginning of experiment 2, the experimenter will have given the participant a set of instructions to read and express to the robot and asked the participant to read the instructions to the robot following they approached the robot at the end of experiment 2. Upon stopping when reversing into position for the other half of experiment 2, the robot transitioned into a finite state machine that will have its gaze stare at the participant but break each so often as if thinking approximately 40% of the time. After each instruction paper is read, the robot either nodded or did nothing, depending on what condition it has been assigned to. Half of the participants remained in the top nod condition (n = 9) and the other half (n = 9) was in the no head

nod experiment. they estimated how quickly the participant read through the instructions. they are wishing to ascertain or at least approximate the level of trust or confidence that each participant has successfully imparted the instructions to the robot, and they feel that how quickly they can read the instructions is a good indication that they think the robot understands the instructions.

This evidence will be compared with more qualitative measures that will be taken in a post-experiment questionnaire, which will wish to use participants' perceptions to validate the metric. When the experimenter finished reading the instructions the robot will leave the room to give the participant the impression that the robot is performing the instructed task. After the robot left, the experimenter returned to the room and the two of them left the room together to administer the final questionnaire, while Willow researchers prepped the room for their study.

3 Results

3.1 Experiment 1

In the first experiment, we tested the gesture condition and verbal condition and evaluated the interaction on different measures (See Table 1 for averages). they measured 7 several items:

1) how many eyes contact the participant gave the robot measured using a video tape and stop watch (for Eye Contact),

2) whether or not they had the proper appraisal for the thought the robot was trying to communicate (for Appraisal),

3) to what extent they felt the robot was attempting to communicate with them (for Attention),

4) how satisfied they felt with the communication (for Comfort),

5) how unnatural the communication felt to them (for Unnatural),

6) how intelligent the robot was (for Intel.), and

7) how socially competent the robot was (for Social Comp.)

All scores in the experiment were taken using a seven-point Likert scale (a rating of 1 to 7) without eye contact which was measured in seconds, and appraisal which was easily a binary representation of whether or not they correctly identified what the robot was communicating. Using R Statistics, they ran an analysis of variance (ANOVA) on each of the items separately and unfortunately found no statistical significance across any of the variables. they also evaluated the data in terms of the gender of the participants but again got no meaningful results.

Table 1: Exp 1 Means

Condition	Eye Contact (sec)	Appraisal (Binary)	Attention (Likert-7)	Comfort (Likert-7)	Unnatural (Likert-7)	Intel. (Likert-7)	Social Comp. (Likert-7)
Gesture	30.7	0.67	4.25	5.83	3.73	4.25	3.92
Verbal	28	0.86	4.86	5.57	3.29	3.86	3.86

3.2 Experiment 2

In the following experiment, they did both a between subjects and within subjects proxemic test.

The between-subjects experiment test was the loose/stiff arms position and the within-subjects experiment test was the approach locus (robot approach human vs human approach robot). All measures were taken and displayed in meters using the data gathered from the robot's laser range finder (See Table 2 for a complete list of averages). Using R statistics, they ran a 2x2 ANOVA on the data and found a few notable results.

Table 2 Experiment 2 Means		
Condition	Robot Approach (m)	Human Approach (m)
Loose arms	0.47	0.59
Stiff arms	0.54	0.62

they found significant results within-subjects ($p < 0.001$) for approach distance. On average, participants let the robot approach them 10 centimeters closer than they would approach the robot. There was also a mildly significant trend ($p < 0.1$) implying that humans averaged 15 cm distance over the robot approach distance when they approached the robot in the stiff arms condition, versus the 5 cm on average in the loose arms condition. This is interesting news because the bouncing arms were only visibly "bouncy" when the robot's acceleration improved after the initial approach, stopped

and then backed up. Maybe operating a few more participants would have yielded meaningful results. they again examined for gender differences and again found nothing.

3.3 Experiment 3

In the third experiment nr 3, they tested what role should the robot nod or can play in creating confidence that the participant-read instructions were understood and the task described was completed. We measured how long the participants took to read the instructions and recorded that in seconds; the rest of the questions were taken from a questionnaire comprised of seven-point Likert scale questions:

1) How confident they were the robot understood the task read to them (for Understood),

2) how confident they were the robot successfully completed the task (for Completed),

3) how intelligent they felt the robot was (for Intelligence)

4) how socially competent the robot was (for Soc. Comp.).

The results are compiled in Table 3.

Table 3: Experiment 3 Means					
Condition	Time (sec)	Understood (Likert-7)	Completed (Likert-7)	Intelligence (Likert-7)	Soc. Comp. (Likert-7)
Nod	58.38	5	4.44	4.88	4.44
No Nod	46.29	3.89	4.33	5.22	4.00

The results of this research reflected a quietly significant result ($p<0.1$) for the timing. Participants in the nod condition equated approximately 12 seconds slower on reading the instructions than participants in the control condition. While this ran counter to our predictions, it becomes apparent very quickly why this was the case. Participants in the nod condition reduced their reading and would not begin reading the next step until the robot had nodded, whereas participants

in the control, the condition did not have such a pause. No other notable results were found, and again they also checked for gender factors but found none. It is also important to note that two participants timed out on this experiment in the no nod condition because they were waiting for the robot to give some indication (like a nod) it was ready to receive the instructions.

Table 4: First Impression		
Experiment	Intelligence	Social Competence
1	4.12	3.90
3	5.00	4.22

Also, at the end of this research, they compared the appraisal of intelligence and social competence from experiment nr 1 and experiment nr 3 and they found a significant trend ($p<0.05$) reflecting that the participants had a significantly bigger appraisal of the robot's intelligence than the more they interacted with it. they had expected to see a first impression effect where the initial appraisals significantly correlated with later appraisals, so this was an interesting surprise, and will be examined more in the discussion section.

4 Discussion

4.1 Implications

The most significant finding they discovered in this study was that in the proxemics research, participants let the robot approach them closer than they would approach the robot. Early work done by Pantofaru and Takayama (2008) was unable to find significant results in this area. The unexpected issue was that this finding runs completely counter to both our hypothesis and the hypothesis of Takayama and Pantofaru. This may have occurred

because of a minute delay during the test in the participant's application for the robot to stop and the robot really stopping, although the p-value was very low, and the robot's stopping distance was not 10 cm, so this is absolutely something that could be explored further in later studies.

There were also additional mildly significant findings. Of particular interest was the finding that participants would not approach the robot as close in the stiff arm condition as they approached the robot in the loose arms condition. This is particularly exciting, largely because the robot's loose arms did generally not appear on the approach, but they were on the stop and reverse. This puts some empirical evidence to theories already utilized in the worlds of animation and acting. This implies participants were more likely to perceive the tight-armed robot as intimidating and therefore would not address it as closely as the loose-armed robot. While these results are far from conclusive, they are very provocative and suggest that there is something very tangible that can be gleaned from the art world and applied to great effect in the world of robotics. The results from this research point to a rich and widely unresearched area of robotics, opening up a new area for researchers to search.

While they were unable to confirm many of the other hypotheses we had at the start of this study, they were able to take away several valuable lessons that they can learn from and develop upon in the future. Most important among these is that it seems everyone possesses a different concept of a robot, and these concepts can vary wildly from person to person. These variations seemed to play a significant impact on our data, as we could not find any significant results. This vital piece of evidence is humbling and shows us how much they underestimated the skeptical nature of the human mind. they cannot follow their members with static, scripted gestures; our participants will remember when they were being duped.

While this is very interesting, it does highlight a significant hurdle that robots must overcome to be able to adopt gestures that fulfill the functionally communicative roles they have set for them. they obviously want robotic gestures to appeal to both sexes, seeing as robots will not just be interacting with women. This indicates that our gestures need to be rich enough to reliably get both men and women to check what they know about robots and other computing devices, and merely look at it as a social agent. We know this is possible; our robotic friends of the science fiction realm have shown us that it is possible to get people of all walks of life and all backgrounds to suspend the concept of mere machine and build upon that further- the concept of social agent (Think WALL-E). In fact, we found that the more the participants interacted with the robot the more intelligent they appraised it. This promising evidence allows us to see that we are making headway in creating robots perceived as intelligent agents. The question then returns back to the researchers and it is three-fold: Do they have a deep enough knowledge of how social gestures work in human-human interactions; do the social gestures reliably translate from human-human interaction to human-robot interaction, and do they have a robotic platform sufficiently sophisticated to adequately implement these gestures?

I find out the answer to the first of these questions is both yes and also no. There is a myriad of studies across several disciplines of social science that identify, define, and even interpret a vast majority of the social gestures we use every day. Still, I feel it would be foolish of us to claim we understand them all. Human-human interaction is so deeply nuanced and has so many levels that we frequently miss even obvious cues in our own personal interactions. Certainly, researchers on the outside looking in on interactions can more easily see some things in an objective light, but so much is subjective that the researcher cannot see and accurately interpret everything. So in a sense, no we do not possess a complete understanding of how gestures work; however, the vast amount of data we do have ought to be able to give us something tangible at this point. Even if we fail to understand the entire picture in micro-fine detail, surely we possess enough understanding to make gestures work in a rudimentary sense.

So then this leads us to the second question: do social gestures from human-human interactions reliably translate to human-robot interactions? The answer to this is a resounding affirmative yes. Think of the robot named Vector we discussed early on. vector the robot performed gestures showing a wide range of human emotion and behavior and the gestures were concluded to be largely interpreted as such. Importantly, the vector was controlled by a human, who could immediately interpret the interactions and seamlessly choose an appropriate response to make the gesture fit with participant expectations. In fact, we need not rely on empirical pictures to know that this is possible. Once again we can point to the world of science fiction and social robots. Even robots as non-anthropomorphic as R2D2 do yet looked at as autonomous social tools and unlike his companion C-3PO, he cannot even talk; he merely beeps and signals. Under these circumstances R2D2 can pull off the humor and even sarcasm as he treks all over the universe; however, like vector, he was non-human only in presentation. Underneath the hood, however, there were a human calling the shots, creating the right combination of bells and whistles to create these advanced communications. So given this, we know for sure that the gestures can translate to human-robot interactions.

We then turn to the platform itself: Do we have a platform adequately sophisticated to perform these gestures? The result here is no, at least for the time being. According to a computational theory made famous by Alan Turing (1950), the only thing that isolates humans from machines is the computer technology has not yet been advanced enough to match that of the human brain; the computational complexity, he argues, is equal. Therefore, in theory, no permanent barricades are preventing us from building a machine as sophisticated as a human. The plain and simple reality is we just are not there yet. We tried to simulate it in our experiment using the PR2, by implementing what is tantamount to an easy song and dance, and our participants were mostly able to see through it. Small tells lived everywhere, & if the participant deviated even marginally of our expectations, they could easily see the man back the screen. The level of sophistication required to pull off a rouse of this magnitude just was not there. All is not lost, however, as new advances in robots and computation are made every day. In the meantime, we should not give up on this research, and if that proposes we must run experiments with a man behind the screen a bit longer, then so be it. The data resolution will be of significant benefit when the robots reach the level of sophistication and it will one day so it makes these gestures feasible.

4.2 Future Work

Of course, many areas for development become readily apparent after the studies have been performed. Amongst these, the first that appears to come to mind is a brief pre-experiment. This research seemed to suggest a prima facie link among peoples' responsiveness to the robot's gestures also any preconceptions they had about robots before they came to the research. We tried to control for peoples' preconceptions by screening for participants with experience with robots but as the preface alluded to, robots in several models are already very prolific in modern-day society so the idea that we could find people that were blank slates on the concept of robots seems a bit unlikely after the fact. We know some participants came in with very strong preconceptions because of comments they made and/or questions they asked throughout this study; for instance, one participant stated robots are just machines doing what they are programmed to do, and therefore cannot be deemed as intelligent. A questionnaire that would give us more quantitative insight into those preconceptions would likely yield some interesting results and allow us to evaluate participants' replies and behaviors in terms of their pre-conceptions. Furthermore, a pre-experiment questionnaire would be helpful in determining to what extent the participant's preconceptions of the robot mattered more than their first encounter with the robot in the part of the first impression of the study. It is possible, though we think unlikely, that the participant's preconceptions weighed so heavily that they colored both the first impression & the second impression. Future research would ideally be better able to control for this kind of variance utilizing this pre-questionnaire.

The first experiment also seemed to have one strong issue that would be worth exploring in the future. Oftentimes, participants were not certain when the transition occurred between when the robot stopped doing the calibration task and when it started gesturing at them in the gesture condition. Frankly, there is the potential to have a whole other study wrapped about this issue.

One concept that is strongly worth investigating is the role eye contact, and more specifically interactive eye contact plays in these interactions. Much of human nonverbal communication comes from facial gestures and in particular the eyes. Perhaps if the robot did any attention-getting activity like waving to the participant, and then somehow loops that attention-getting activity until the robot senses it has the participant's eye contact; then it could begin the gesture with increased certainty that the participant has noticed the robot. In our own human-on-human interactions, this fits perfectly with what we would assume. A person does not just approach a stranger on the street and say, "what time is know ?" There is normally some sort of introduction, such as, "Excuse me" or "I'm sorry to bother you." Both of these introductory phrases secure the person's attention, and normally, we do not proceed into the next part of the question until the introduction has been recognized(oftentimes simply with eye contact). The experiences of this research suggest usefulness for this sort of interaction to be performed and utilized by a robot.

Experiment nr 1 also suggested the importance of the robot keeping and maintaining eye contact by the participant throughout the gesture and using it to reinforce the idea that the robot was gesturing at the participant. The eye contact the robot did make in the first experiment meant just having the robot's head turn to face where the participant was supposed to be. Some of our more tech-savvy participants really wanted to test this to see to what extent the robot was interacting with them and got up and moved around the robot to see if it tracked them, and of course, it did not.

This for many of them was sufficient to reveal the man behind the curtain, and their evaluation of the machine was significantly lower. Had the robot been more dynamically involved with the participant, the robot would have followed the person with its head movement. The drawback is that the head tracking would have been "jerky" and, for lack of a better term, robotic. This could have appeared in lower appraisals of the interaction because it would also effectively reveal the man behind the curtain. The result needs to rely on smooth implementation of face tracking and if that can be handled successfully, we believe the robot will make great strides in its effectiveness in interacting with humans.

Experiment nr 2 had one major fault that we were unable to address and remedy while simultaneously maintaining the integrity of the experimental design within the given time frame. The loose arms condition in the experiment did not yield as much bouncing or movement as we would have liked to have seen, and a large part of that is that the robot has a naturally smooth ride. Peoples' arms bounce when we walk because we have two legs and therefore a certain level of bounce is needed to move and that can be either exaggerated or minimized in given situations. The PR2 Robot has wheels on a solid platform and therefore was lacking that natural level of bounce.

Combine that with level, smooth floors, and the fact that proxemics studies need the robot to move in a straight line towards the participant, there are simply not many opportunities to have outside forces (such as momentum, etc.) act upon the robot's arms. One interesting observation we did make, however, is that with the arms controllers off if the robot does not move in a straight line, the arms will drift and bounce quite eccentrically. The movement of the arms in those instances was vaguely reminiscent of the movement of Captain Jack Sparrow's arms in the Pirates of the Caribbean movie series. While we were intrigued by this action, it was discovered too late to incorporate it into our research in any form but was something we certainly wanted to note here if we hoped to get more concrete results involving the loose arm/stiff arm question for increasing levels of comfort in human interactions in future performance.

The last experiment was challenging in many senses. First and foremost, the idea of trust means many different forms to many different people. While they attempted to get around that by not explicitly referring to the idea of trust, the participants' methods for evaluating the questions they had them answer regarding their confidence in the robot's performance varied greatly depending on how their particular sense of trust is formulated. Some participants recorded that they had no confidence in the robot's performance because they did not see any tangible effects. Others were perfectly willing to claim with absolute certainty that the robot accomplished the task properly because the robot merely looked at them while they were reading instructions. One idea to help control for this extreme variance is to make the instructions very simpler. One reason why the variance could have happened so great is that as noted above, participants came in with widely varying preconceptions of robots. If any of the participants were technically inclined in the slightest (and given our population sample was mostly Stanford seniors and other residents of Silicon Valley, it is fairly reliable to think many were) they may have immediately realized that if the robot successfully completed the instructed task, it would be a major technological invention that would have likely been wildly publicized. So perhaps this is what gave our rouse away to some of our more jaded and cynical participants, and ended in them demanding proof of task achievement before trust would be granted to the robot. The thought is, however- if we make the robot's task more achievable, and ergo more plausible, people may be more willing to be trusting of the robot's performance. This can be done merely by simplifying the task. We made the task long by design to be certain that the robot's head nodding would not be ignored, but participants appeared to readily notice the nodding, so it may be safe to sacrifice the number of nodes in order to explain the instructions a bit, and perhaps rein in some of the drastic variability of the participants' willingness to give trust to the robot.

5 Conclusions

I started this research hoping to learn something valuable about robots from the early research that has been done on robots and in the end, they rediscovered something valuable about ourselves that they had underestimated. We are all individuals living a social life and not one of our interactions with any person is ever equal twice. Our interactions are highly effective and very responsive to even the smallest changes in the person or the environment.

Our robot researchers were unable to keep the interactions dynamic enough to fool the ever-critical human brain, but even this humble reminder of our robot's shortcomings presents us with valuable insight. Now our focus needs to be how do we take this newly rediscovered knowledge about ourselves and turn it into something of value as we continue to strive for advancements in the field of human-robot interaction.

As discussed earlier, it will remain important for us to continue to investigate what roles these gestures can play in facilitating human-robot interactions, but until we can have robots interact with humans more dynamically, we will need to leave the interpretation of the social scenarios & decision-making to the thought of another human. The field is still rich for mining valuable data on human-robot interaction, and if we continue to search and broaden our understanding of the roles these gestures can play when robot technology is ready to hold dynamic interactions with humans, we will have an impressive arsenal of tested and proven gestures able to be implemented and tested autonomously. We know technology will advance to that point; now it is only a question of how long will we have to wait to understand it.

How long till the robots of science fiction can become reality? Any definitive answer to that question would merely seem a mirage, constantly moving farther into the way the closer we will get. Finally is the best and most accurate approximation we can give right now. People did not evolve into the social animals we are today overnight, and neither should we assume robots to develop in a similar matter. It took billions of years for humans to go from nothing to what we see today. It has only taken robots the better part of a century to achieve the sophistication we have now, and the future possibilities seem virtually unlimited. So perhaps the usual appropriate answer to the first question posed in the preface- "Can robots ever hope to be human?", the answer in my own opinion is yes, eventually.

Appendix

Willow Garage Study platforms

The platforms used for the other half of the research(conducted by Willow Garage staff) used a different robotic platform called the Texai (Figure 6). As can be seen, the robot is merely a mobile webcam with an LCD screen combination. These assists ensure that there is no pollution between studies.

There were further times when Willow Researchers conducted a different study prior to the research discussed here. Again in those examples, a different robot platform was used, in this case, the Turtlebot (See Figure 7). The robot is essentially an iRobot Roomba with an Xbox Kinect on top of the robot.

Figure 6: Texai

Figure 7: Turtlebot

Experimental Protocols

1. the Participant enters the office, and the receptionist has him waiting in the lobby area for the experimenter.

2. the Experimenter enters the lobby and greets participants; takes them on a brief introduction to the PR2 robot.

3. Trip ends in the pool room where the experimenter says, “I have a consent form for I need you to fill out.”

4. the experimenter provides the participant consent forms to fill out and reveals the participant to a table near the PR2 robot that is going into pseudo-calibration motions.

5. If they are asked by the participant, the Experimenter should answer: “This PR2 robot is currently calibrating its cameras. It’s a lengthy and difficult process.”

6. the Experimenter leaves forms with the participant & moves to another side of the room and appears to be engrossed in paperwork, but actually is starting a camera.

7. After the participant does the consent paper form, the experimenter tells them he forgot to print the paper and asks the participant to wait at the table while he goes to get it.

8. Quickly following after the experimenter leaves his place, the robot stops the calibration task and begins one of the experimental requirements.

9. After the experimenter returns with the paper of the form, the Experimenter should ask if everything went well and ok.

10. If the participant says something about the PR2 robot needing something, needing help, or else, they should be advised to guess what exactly they needed (e.g. What does it need? What’s wrong?)

11. the Participant is then led to a separate room and given a post Experiment nr 1 questionnaire, while the experimenter notes what comments the participant made and turns

off the cameras. If needed the experimenter can clarify which robot that they are answering questions on.

12. the Experimenter guides the participant on the long way to a primary research room with roads to the store and burns room, while the confederate runs the PR2 robot to the primary area room, and adjusts height according to the height of the participant in the research room. Also places the arms to be either loose or firm as the pre-determined condition needs.

13. the Participant enters the room for the next experiment nr 2; the experimenter guides the participant where to be and stand.

14. the Experimenter will give a script text to the participant for further instructions.

15. the Experimenter: “In this research, the PR2 robot will approach you. All you need to do is order it to stop when it’s on the edge of your comfort place. Then take a step backward, and the robot will do the same. Then approach the robot and read these instructions. Be certain and clearly when you speak clearly so the PR2 robot can process all the instructions. The robot will then run off to perform the instructions. Wait in the room for more/further instructions.”

is the state to which the participant is in.

16. the Confederate will command and control the PR2 robot remotely for the “stop” command when it needs it, and also for the head-nodding if that

17. The experimenter should returns to the room quickly after the robot leaves its place and takes the participant out of the room to administer the final questionnaire.

18. Then the Texai robot experiment starts.

Experiment 3 Participant Script

Note it is very important to flow the next: Please research purpose try to speak as clearly as possible so that the PR2 robot can perfectly process the instructions you give it.

I am going to read a list of steps for completing a ball fetching task that must be completed in the order I say them:

1. Exit the research office.
2. Turn left and proceed down the research hallway until another hallway begins on the right.
3. Turn right onto this research hallway and drive the robot forward past the four offices on the left.
4. Enter the next research office on the left & pick up the red ball sitting on the desk in that office.
5. Exit the research office.
6. Turn right and drive the robot forward down the research hallway past the two offices on the right.
7. Enter the next research office on the right and place the red ball on the office desk.
8. Exit the research office.
9. Return to the recharge station.

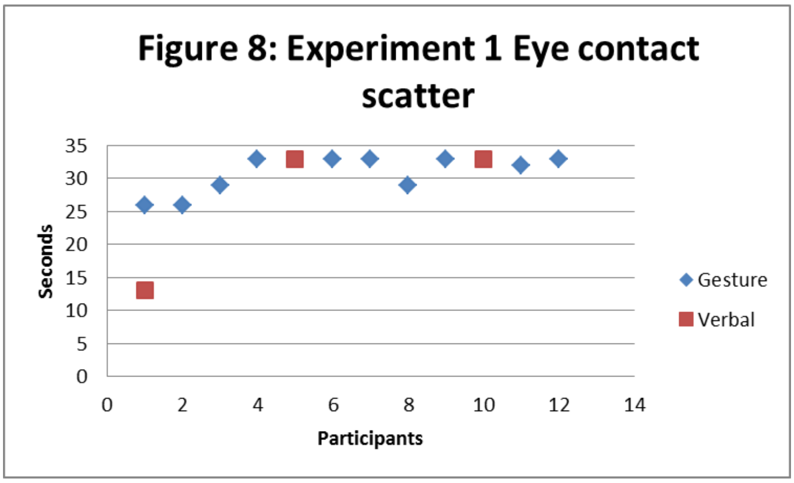


Figure 8: Experiment 1 Eye contact scatter
Seconds
35
30
25
20
15
10
5
0
0
2
4
6
8
10
12
14
Participants
Gesture
Verbal

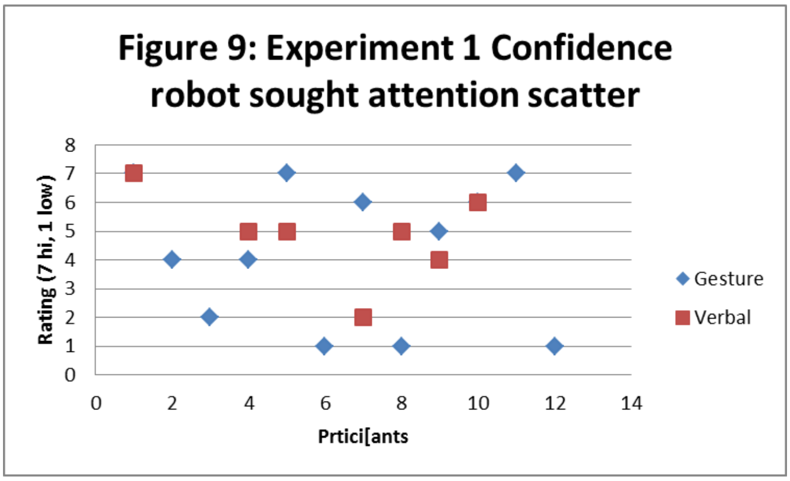


Figure 9: Experiment 1 Confidence robot sought attention scatter
Rating (7 hi, 1 low)
8
7
6
5
4
3
2
1
0
0
2
4
6
8
10
12
14
Prtici[ants
Gesture
Verbal

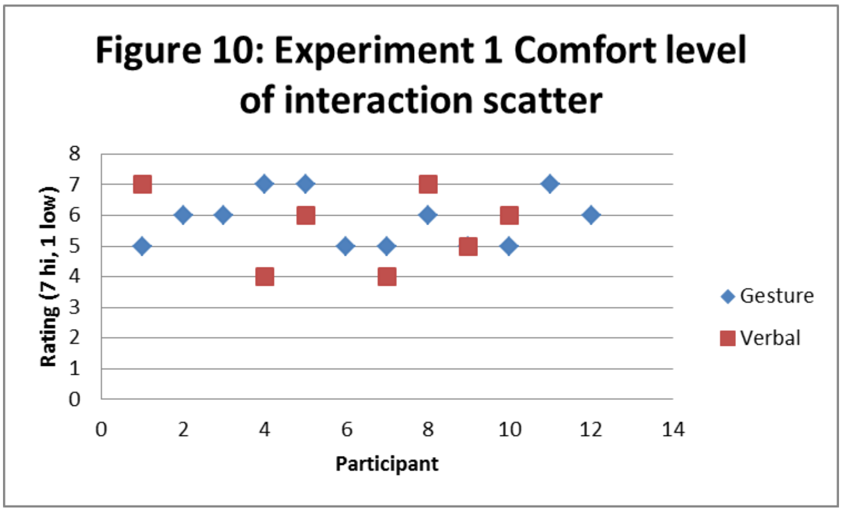


Figure 10: Experiment 1 Comfort level of interaction scatter
Rating (7 hi, 1 low)
8
7
6
5
4
3
2
1
0
0
2
4
6
8
10
12
14
Participant
Gesture
Verbal

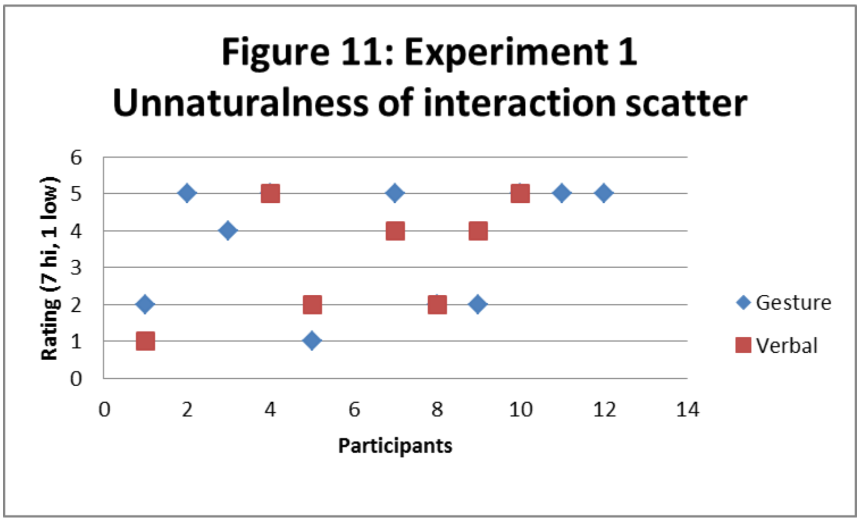


Figure 11: Experiment 1 Unnaturalness of interaction scatter
Rating (7 hi, 1 low)
6
5
4
3
2
1
0
0
2
4
6
8
10
12
14
Participants
Gesture
Verbal

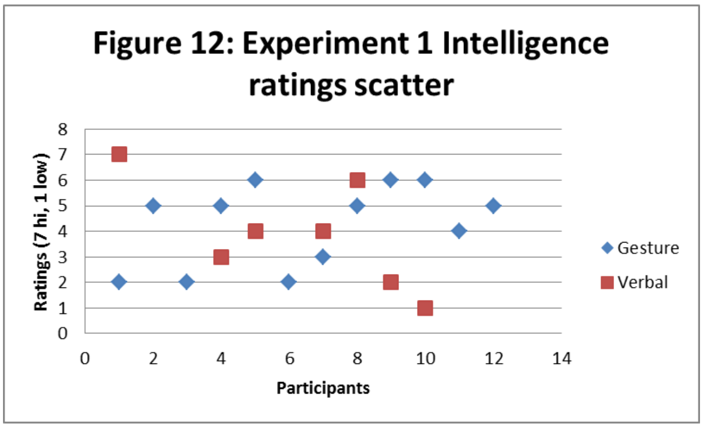


Figure 12: Experiment 1 Intelligence ratings scatter
Ratings (7 hi, 1 low)
0
1
2
3
4
5
6
7
8
0
2
4
6
8
10
12
14
Participants
Gesture
Verbal

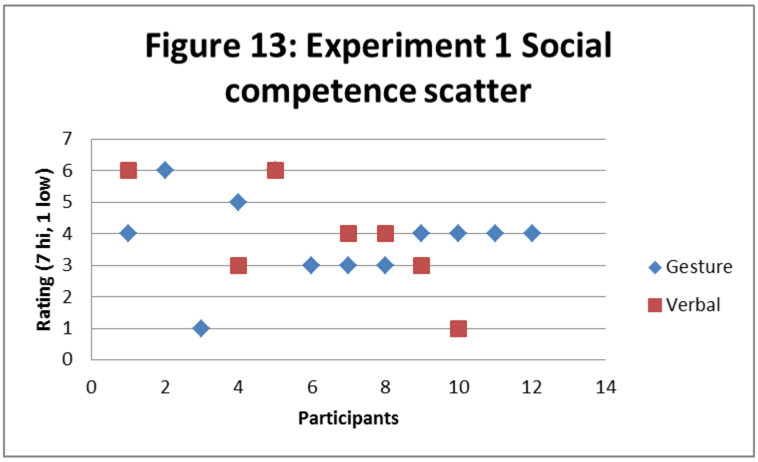


Figure 13: Experiment 1 Social competence scatter
Rating (7 hi, 1 low)
0
1
2
3
4
5
6
7
0
2
4
6
8
10
12
14
Participants
Gesture
Verbal

Figure 14: Experiment 3 Instruction reading time scatter

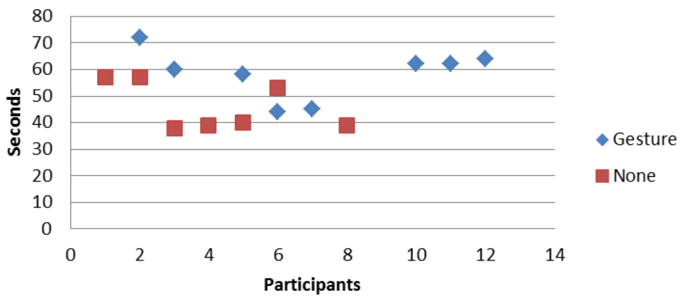
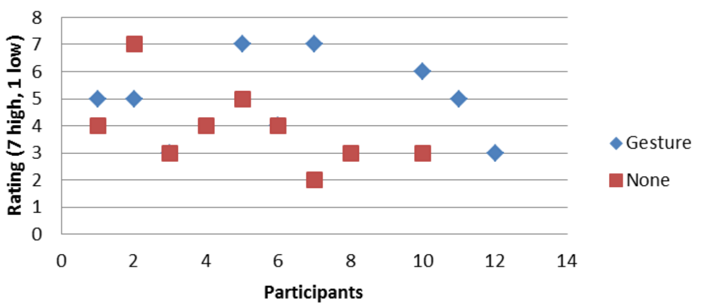


Figure 15: Experiment 3 Confidence robot understood scatter



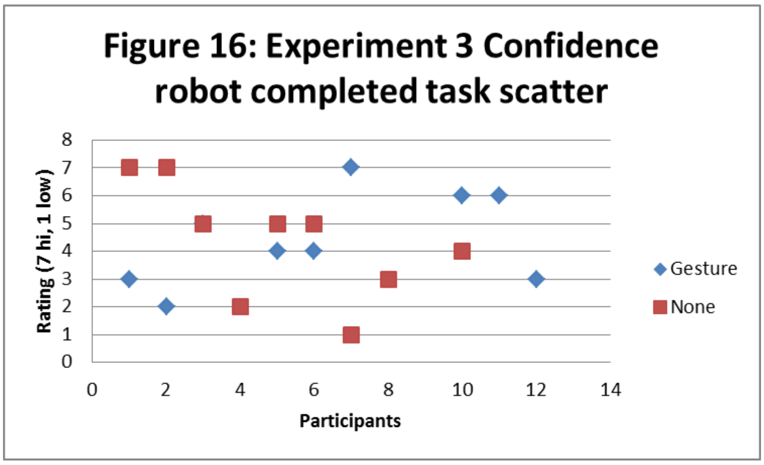


Figure 16: Experiment 3 Confidence robot completed task scatter
Rating (7 hi, 1 low)
8
7
6
5
4
3
2
1
0
0
2
4
6
8
10
12
14
Participants
Gesture
None

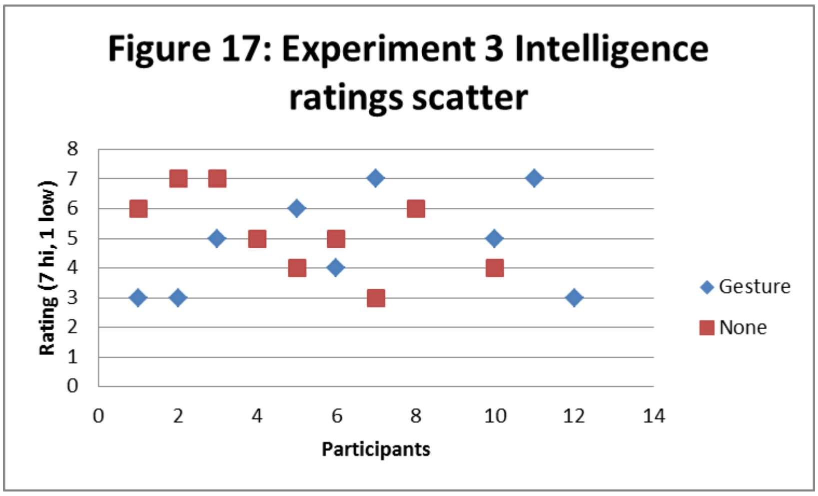


Figure 17: Experiment 3 Intelligence ratings scatter
Rating (7 hi, 1 low)
8
7
6
5
4
3
2
1
0
0
2
4
6
8
10
12
14
Participants
Gesture
None

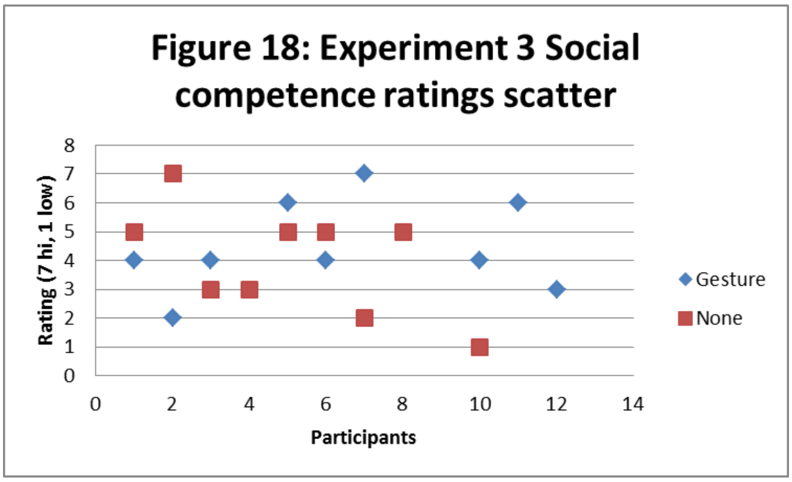


Figure 18: Experiment 3 Social competence ratings scatter
Rating (7 hi, 1 low)
8
7
6
5
4
3
2
1
0
0
2
4
6
8
10
12
14
Participants
Gesture
None

References

Adams, D. (1978). The Hitchhiker's Guide to the Galaxy. United Kingdom: Pan Books.

Bruemmer, D., Few, D., Goodrich, M., Norman, D., Sarkar, M., Scholtz, J., Smart, B., & Swinson,

M. L. (2004). "How to Trust Robots Further than We Can Throw Them." In CHI Extended Abstracts.

p. 1576-1577.

Byers, Z., Dixon, M., Smart, W. D., and Grimm, C. (2004). "Say Cheese! Experiences with a Robot Photographer." AI Magazine. 25(3). p. 37-46.

Feldman, R. S., Phillipot, & P., Custrini, R. J. (1991). Social competence and nonverbal behavior. In

R. S. Feldman & B. Rimé (Eds.), Fundamentals of Nonverbal Behavior (p. 329-350). Cambridge: Cambridge University Press.

Freedy, A., DeVisser, E., Weltman, G. & Coeyman, N. (2007). "Measurement of Trust in Human- Robot Collaboration." In Proceedings of the 2007 International Conference on Collaborative Technologies and Systems. p.

Hall, E. T. (1966). The Hidden Dimension. New York: Anchor Books.

Johnston, O., Thomas, F. (1995). The Illusion of Life: Disney Animation. New York: Disney Editions. Kurtz, G. & Lucas, G. (1977). Star Wars Episode IV: A New Hope. United States: LucasFilms.

Lee, J. D. & See, K. A. (2004). “Trust in Automation: Designing for Appropriate Reliance.” Human Factors. 46. p. 50-80.

Morris, J., Collins, L., Lasseter, J., & Stanton, A. (2008). WALL-E. United States: Pixar Animation Studios.

Oosterhaut, T. V. & Visser, A. (2008). “A Visual Method for Robot Proxemics Measurements.” In Proceedings of 3rd ACM/IEEE International Conference on Human-Robot Interaction Workshop on Metrics for Human-Robot Interaction.

Scheef, M., Pinto, J., Rahardja, K., Snibbe, S., & Tow, R. (2000). “Experiences with Sparky: A Social Robot.” Proceedings of the Workshop on Interactive Robot Entertainment.

Shibata, T., Yoshida, M., Yamato, J. (1997). “Artificial Emotional Creature for Human-Machine Interation.” Proceedings of IEEE Intl. Conf.Systems, Man, and Cybernetics. 3. p. 2269-2274.

Takayama, L. & Pantofaru, C. (2009). “Influences on proxemic behaviors in human-robot interaction.” In Proceedings of the 2009 IEEE/RSJ international conference on intelligent robots and systems. p. 5495–5502.

Turing, A. (1950). “Computing Machinery and Intelligence.” Mind. p. 433-460.