Animal–Robot Interaction: The Role of Human Likeness on the Success of Dog–Robot Interactions

Maretta Morovitz[1], *Megan Mueller*[2], *and Matthias Scheutz*[1]

[1]*TuftsUniversity, UnitedStates*
[2]Cummings School of Veterinary Medicine, Tufts University, United States

maretta.morovitz@tufts.edu, megan.mueller@tufts.edu, matthias.scheutz@tufts.edu

Abstract

Animals, and specifically dogs, are present throughout our social spaces which nowadays are increasingly populated with technology. Past research has mostly investigated interactions between humans and robots, failing to address possible effects of this technology, on animals, such as canines, in homes and in particular the possible utility of using robots for animal care. However, for dog–robot interactions to be successful and effective, dogs must accept robots and display positive behaviors towards them. Thus, research must determine possible robot characteristics such as particular movements or vocalizations that might be able to facilitate the dog's trust in and acceptance of the robot. The goal of the present exploratory study was to investigate the reaction of dogs to a small humanoid robot under different conditions of vocalization and movement. Our main finding from these dog–robot interaction experiments is that dogs unacquainted with the robot prefer robot vocalizations to robot movement.

Terms: animal–robot interactions, dog–robot interaction experiments, human likeness

1. Introduction

Dogs live in homes, work with our police and military, and are present on commercial farms. Already these three specific groups of dogs have begun to see robotics incorporated into their traditional living spaces. In regard to the first group, the technical world has seen much excitement and innovation in the field of social robotics as our society prepares itself to accommodate the needs and social requirements of an aging population [1]. As a result, robotic research has started to investigate the use of social robots in the home for companionship and help with daily tasks. Dogs in these homes, therefore, have begun to see robots as part of daily life. Additionally, with more adults working longer into life [2], many dogs find themselves alone for significant periods of time. Canine robotic toys, focused particularly on the social needs of dogs, have been introduced to help alleviate the loneliness and agitation expressed by these home-bound dogs [3, 4]. In regard to the second group of dogs, military and police work has begun to rely on robots for tasks previously accomplished by dogs [5]. However, until robotics can utilize the full agility of a dog, both canine and robot will have to work together to accomplish tasks [6]. Finally, as large farms increasingly turn to technology and robotics, farm animals have been increasingly required to interact with this new technology [7]. Thus, by designing robots specifically to interact with these farm dogs, we can create more synergistic partnerships between canine and machine. While these examples of potential animal–robot interaction differ greatly, they share the same root requirements. In each of these situations the dog must accept the robot in order for the interaction to be successful and effective. Thus, research must determine the robot characteristics necessary for facilitating the dog's trust and acceptance. The goal of this research is to begin to guide designers to create robots with features and functionalities most beneficial to establishing and maintaining effective dog–robot interactions, especially as they relate to the human likeness of the robot. For this study we focused on two aspects of human behavior, vocalization and movement. In the **human** condition, the anthropomorphic robotic agent will vocalize and move like a human, while in the **nonhuman** condition the robot will remain silent and stationary. After the interaction, in both conditions, the robot will offer the dog a treat. The culmination of the dogs behaviours throughout the interaction, and its acceptance or rejection of the treat will be used to determine the eventual success or failure of the interaction.

2. Previous Work

As the presence of technology grows in our society, fields such as human–computer interaction (HCI) and human–robot interaction (HRI) have expanded to include animal–robot interaction applications. Past research has suggested that the extension of HCI and HRI into animal–robot interactions could lead to insights in inter-species relationships in the areas of animal cognition, conservation, food production, and even expanding human–computer interaction knowledge [8, 10]. Devices including the FIDO vest [13] and Dog PC [14] represent technology designed specifically for canine users. Additionally, the Canine Assisted Robot Deployment (CARD) robots were designed specifically to work in conjunction with Urban Search and Rescue (USAR) dogs [15]. In field tests, CARD was identified as a "viable technique for delivering a response robot through challenging terrain to a casualty of an urban disaster" [15]. However, while the existence of these technologies lends support to the importance of dog–robot interactions, the device designs fail to examine the aspects of the interaction that contribute to its efficacy and success. This question was addressed in research conducted at Eötvös Loránd University which investigated social dog–robot interactions and examined the effect of social signals displayed by an unfamiliar robot [9]. This study concluded that "the level of sociality shown by the robot was not enough to elicit the same set of social behaviours from the dogs as was possible with humans, although sociality had a positive effect on dog–robot interactions." While not as successful as a human–dog interaction, by utilizing known social cues, the success of the interaction increased. Therefore, the research suggests that the dog is able to recognize and respond to human social cues from a nonhuman agent. Our study will take the next step and determine if the use of a robotic agent that displays humanlike behaviors, namely vocalizations and movement, will increase the success of the interaction compared to a robotic agent that does not display humanlike behaviors.

3. Experiment

Based on the work outlined previously, we hypothesized that a dog would be more likely to accept a treat from and act positively towards a robot displaying humanlike behaviors than a robot that fails to display humanlike behaviors. To test our hypotheses, we designed a fully between-subjects investigation of the effects of human-likeness on dog–robot interactions. After a brief interaction with a robot, which either acted humanlike or nonhuman-like, the robot offered the dog a treat. Dogs then had a set amount of time to take the treat. The robot then walked directly towards the dog. At the conclusion of the interaction, the human researcher offered the dog a treat. All behaviors during the entirely of the dog–robot interaction were recorded.

3.1. Materials & Methods

3.1.1. Equipment

- **Robot** The robotic agent used for this study was the Nao programmable humanoid robot developed by Aldebaran Robotics. The robot was programmed using Choregraphe to complete a pre-scripted set of vocalizations and movements. Vocalizations were performed by a female human voice. Vocalizations include calling out the dog's name and using phrases such as "Good dog" and "Come here, buddy" and "Do you want a treat?". Movements included, offering the dog a treat by extending and opening the robot's hand, waving the robot's hands, walking side to side, turning the robot's head to follow sounds, and swaying back and forth as part of the Nao's Autonomous Life mode. During the first 10 seconds of the interaction, the robot stands (movement alone), speaks to the dog using its name (vocalization alone), and walks side to side while speaking to the dog using its name (vocalization and movement combined). The remainder of the interaction includes vocalization and movement together.
- **Dog Treat** The dog treat used was the Milk-Bone MaroSnacks Dog Treats for All Sizes Dogs.
- **Study Environment** The study environment was an empty room that contained only the Nao robot. During the interaction with the robot, only the owner and dog were present. The researcher was present in the room at the conclusion of the interaction.

3.1.2. Participants & Procedure

A total of 14 owner/dog teams participated in this study. All dogs were at least 6 months of age. Dogs remained on a leash for the entirety of the interaction, but owners were advised to allow their dog complete freedom to explore the space. Owners were also instructed to avoid all interactions with their dog to avoid influencing behavior. Upon informed consent owner and dog entered the study environment. As the dog entered the room the robot stood. In the **human** condition, the robot then continued to talk and move for the next three minutes. In the **nonhuman** condition, the robot stood on entering, but remained silent and still for the same time period. At the end of the time, the robot raised its arm and opened its hand to offer the dog a treat. In the **human** condition, this action included a vocalization "Would you like a treat?". As soon as the dog took the treat, the robot would walk forward, directly towards the dog. In the event that the dog did not take the treat, the robot would walk forward after 3 minutes. After this action, the researcher enters the room and offered the dog the treat. If the treat was not accepted, the researcher offered the uneaten treat. If the treat was accepted, the researcher offered an identical treat. This action concluded the interaction.

3.1.3. Control

A human researcher offered the dog a treat to ensure that, in the case the dog did not accept the treat when offered by the robot, this rejection was not due to the treat itself.

3.1.4. Independent Variable

We manipulated the robot's human likeness. The **human** condition used vocalizations and movements to mimic normal human–animal interactions. The **nonhuman** condition did not use any such vocalizations or movements.

3.1.5. Dog Behavior Assessment Measures

After analyzing video from each interaction, we used qualitative assessment measures [11] to categorized three subsets of behavior types: positive, negative, and neutral. A positive behavior corresponds to a behaviour that shows affinity for the robot, such as smelling the robot, cocking of the head, and approaching the robot [16]. A negative behavior corresponds to a behavior that shows a disaffinity for the robot, such as backing up, growling, head and tail down [17, 16] (Figure 1). A neutral behavior is one that shows neither affinity nor disaffinity towards the robot, such as smelling the room, laying down or sitting without looking at the robot, or trying to play with the owner.

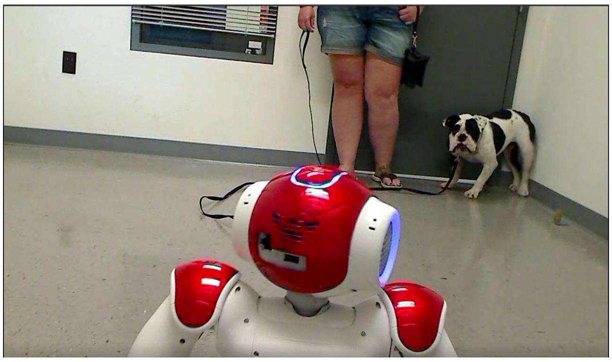

Figure 1: *On average dogs in the* ***nonhuman*** *condition displayed negative behaviors more often then they displayed positive behaviors during the interaction*

3.2. Results

Each interaction was analyzed using the following questions:

1. Did the dog accept the treat from the robot? From the human researcher?
2. When did the dog display negative, positive, and neutral responses during the interaction?

3.2.1. Acceptance of Treat

Out of 14 interactions, a total of 4 dogs, all in the **nonhuman** condition, accepted the treat from the robot (Figure 2). This

Figure 2: *All dogs that accepted the treat were part of the* ***non-human*** *condition*

number is equivalent to 28.6% of all dogs who participated in the study (14 dogs) or 57.1% of dogs who participated in the **nonhuman** condition (7 dogs). All dogs in both conditions accepted the treat from the human researcher.

Table 1: *Breakdown of Dog Behavior Based as Percentage of Entire dog–robot Interaction*

	Negative	**Positive**	**Neutral**
Human Condition			
Mean	38%	14%	48%
SD	0.33129307600	0.09068897300	0.25564644000
SEM	0.12521701288	0.03427720989	0.09662527197
Nonhuman Condition			
Mean	4%	41%	54%
SD	0.06020373600	0.14420790000	0.18573626200
SEM	0.02275487335	0.05450546293	0.07020170839

Table 2: *Unpaired t-test results for means between conditions*

	t	**df**	**standard difference of error**	**p**
Negative Means	267.1533	12	0.127	<.0001
Positive Means	419.3349	12	0.064	<.0001
Neutral Means	50.2365	12	0.119	<.0001

3.2.2. Dog Behavior Breakdown

After marking the videos according to the aforementioned criteria, the resulting breakdown showed that overwhelmingly, the dogs in the **human** condition displayed more negative behaviors than positive behaviors (Figure 3). The mean percentage of time spent displaying each behavior type during the course of an interaction can be seen in Table 1. In the **human** condition, an average of 44% of the interaction was categorized as a negative response, while 17% and 39% were categorized as a positive and neutral response, respectively. In contrast, during the **nonhuman** condition, an average of 4% of the interaction was categorized as a negative response, while 41% and 54% were categorized as a positive and neutral response, respectively. Using an Unpaired t-test (Table 2) to compare the means for each behavior category between the **human** and **nonhuman** conditions, it was determined that all differences between conditions are extremely statistically significant. These mean values show that the **nonhuman** condition elicited a far more positive overall response than the **human** condition. However, while the positive response is higher in the **nonhuman** condition, so is the neutral response.

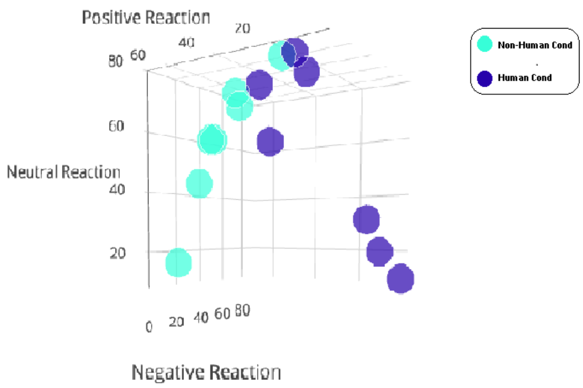

Figure 3: *3D Scatter Plot of Dog Behaviors as a Percentage of Time of dog–robot Interaction.*

3.2.3. Initial Behaviors Towards Robot

Table 3 lists the initial behaviors during the first 10 seconds of the interaction.We see that 29% of the dogs reacted positively to movement only, 100% acted positively to vocalization only, 29% acted positively to a combination of vocalization and movement.

Table 3: *Breakdown of dog behaviors during first 10 seconds of* ***human*** *condition*

	Movement Only (2 secs)	**Vocalization Only With and Without Name (5 secs)**	**Movement and Vocalization Combined (3 secs)**
1	negative	positive	negative
2	negative	positive	positive
3	negative	positive	negative
4	positive	positive	negative
5	negative	positive	positive
6	positive	positive	negative
7	negative	positive	negative

4. Discussion

Will a dog react more positively to a robot that acts human-like, compared to robot that does not act human-like? Based on previous research [9] we expected that the dogs would react more positively to a robot that demonstrated humanlike vocalizations and movements than one that did not. However, as can be clearly seen in Table 1, this hypothesis was not supported. Dogs in the **human** condition displayed higher percentages of negative behaviors than positive behaviors, while dogs in the **nonhuman** condition displayed higher percentages of positive behaviors than negative behaviors. In all cases, the dogs displayed positive behaviors to the researcher, by accepting the treat. Additionally in the **nonhuman** condition, the dogs displayed higher percentages of neutral behaviors. These behaviors represent periods of time where the dog shows no interest in the robot. Robotic designs that will operate in shared spaces with dogs, without the primary goal of facilitate dog–robot interactions, may benefit from incorporating these nonhuman characteristics, as it would allow the robot to operate without interfering with the dog's activity. However, designs that seek to facilitate dog–robot interactions may not be aided by implementing nonhuman characteristics alone, as this may cause a neutral behavior from the dog and impede the interaction. Examining Table 3, we can clearly see the pattern of the dog's initial behaviors to the robot. All of the dogs were comfortable with the initial vocalizations alone. Many of the dogs reacted negatively to either the movement alone, or the combination of vocalization and movement. Interestingly, no dog reacted positively to both the movement alone and the combination of vocalization and movement. These observations suggest that vocalizations could be used to elicit a positive response, especially when the dog's name or a known command is given in a human voice. Thus, vocalization may be successful in creating an initial relationship and allowing for other actions, such as movement, to happen in the interaction after an initial trust between robot and dog is formed. However, since this study combined vocalizations and movement simultaneously after the first 7 seconds, further research is necessary.

4.0.1. *Limitations and Future Directions*

This study represents one of the preliminary attempts to study the effects of human likeness on a dog–robot interaction where the dog is the primary agent interacting directly with the robot with no cues from a human counterpart. However, there are a number of limitations of this study, which illustrate avenues for additional research in this area.

Population size By and far the largest limiting factor of this study was the number of participants. With a larger sample size, this study could be further expanded and factors such as age, breed, disposition, and whether the dog is treat or toy motivated could have been analyzed to determine if they effect the interaction. As most of the dogs lived in the surrounding area, the population was fairly homogeneous consisting of small to medium sized family dogs. This population is ideal when considering dogs who will be exposed to the continued integration of social robotics in the home. However, as robotics continue to be incorporated into our society, policy/military dogs and farm dogs will be expected to interact closely with robots for working purposes. Thus future work will need to incorporate these dogs, as they are exposed to different stimuli and have differing levels of obedience training than family dogs.

Owner–dog interactions Another limitation of this study was that dogs remained on a leash for the interaction. Had the dogs been allowed off the leash and to enter the room alone, we suspect we would have seen different behaviors. Often, when scared or threatened, the dogs retreated behind their owners. Additionally they were often confused as to why their owners were not interacting with them as they ordinarily would have and displayed more interest in their owner than the robot.

Mode of Evaluation Each of the dog's interactions during the study was categorized as positive, negative, or neutral. This analysis was done using qualitative assessment of behaviour methods [11]. While there is support for this method of assessment [12], the use of instrumental methods of assessment [11] may be necessary if the study is expanded for longer interactions with more participants, as manual behavior coding may no longer be possible.

In terms of future directions, an important next step is to separate vocalizations and movement. This study showed that the combination of vocalizations and movement were not successful in eliciting a positive behavior from the dog. However, future work should investigate if the same behaviors would be found from interacting with a robot that performs only one of these two actions, or uses vocalizations to establish trust before movement. Additionally, specifically looking at vocalizations, further work must be performed to determine if word choice (i.e., use of words known to the dog, such as its name or trained commands) or voice type (i.e., male, female, computer) influence dog behavior. Finally, the dogs' aversion towards the robot's movements may have been due to the fact that the movement, while humanlike, did not match perfectly with normal human behavior. For example, while the act of walking is humanlike, the robot walked using jerky robotic steps. Additionally, while the robot sounded and moved in a humanlike manner, it did not possess other qualities such as human scent which dogs ordinarily use to distinguish humans. These inconsistencies may have resulted in a form of a canine Uncanny Valley, where the inconsistencies between the robot and a human prevented the dog from accepting the robot. However, while these inconsistencies may have resulted in negative responses at first, it may be that, as the dogs get more comfortable with this new robotic stimuli over time, they will accept it. Thus a future study which introduces dogs to robots on multiple occasions would be needed to determine if, after repeated exposure, the dogs would become more comfortable and accepting of the robot and respond more positively to a combination of vocalization and movement than to either action alone.

5. Conclusion

The primary aim of this exploratory research was to determine the effect of human likeness, in the forms of movement and vocalization, on animal–robot, and specifically dog–robot interactions. From the above results it can be concluded that dogs more frequently displayed negative behaviors towards humanlike robots and more frequently displayed neutral and positive behaviors towards nonhumanlike robots. By examining the initial behaviors displayed, we found specifically that the dogs displayed more positive behaviors towards vocalizations than towards movement. Further studies will be required to evaluate whether vocalizations compared to non-vocalizations are preferred, and whether repeated interactions might be able to mitigate the initially negative effects of movements.

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