Creating Interpretable Social Cues from Robo-pets in Human-Robot-Interaction

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Abstract

Within the realm of human-robot interactions, context is very important for zoomorphic robots. When humans are approached by zoomorphic robots without proper context, they are often confused with how to interact with this robot. This can create a big problem in the field of HRI because if a robot's user can not discern the intent of a robot, user experience as well as efficacy of the robot will suffer greatly. Our study analyzes how humans naturally react to zoomorphic robots when these robots perform different actions to display intent of a requested task. To tackle the idea, we conducted an experiment where we simulated a robotic pet ("robopet") using a Turtlebot4. This robopet approached our users and conducted one of two actions, eliciting different reactions from the user. The robopet has a deliberate control architecture, used Simultaneous Localization and Mapping (SLAM) for navigation, and outputted pet like movements. Our research is similar to past studies that have focused on robotic animals, however our study builds on these by focusing directly on the expression of intent and how that effects user experience and robot efficacy. Our evaluation metrics were task compliance, time to act, user experience, and interpretability. Overall we found that our Bark command elicited a better user experience and faster time to act, but our Bump command was more easily interpretable and led to a higher rate of successful task completion. Our results are useful for HRI because we explicitly show how the different levels of interpretability of zoomorphic actions can affect user experience and ability of users to complete a non-verbalized task; implying that it is worthwhile to continue studying the best method to display intent. Future researchers can use these results to model their own experiments or move forward with actions that we tested.

1. Introduction

Perception is defined as "a way of regarding, understanding, or interpreting something; a mental impression." It is no secret that robots are becoming more and more ubiquitous in today's age (Mcneal 2015)[5]. Some robots are even suggested to some humans to be a companion in life to mitigate their loneliness[7][8]. To ensure that these robots are actually performing their desired functions and cohabitate with users as intended, it is extremely important that robot designers and researchers focus on the display of intent for their robots (Rosen et al 2017)[9]. It would be ideal to design a robot's actions in a way that humans can perceive the intention with minimal cognitive work. However, with limited functionality (i.e. lack of anthropomorphic features, lack of mobility etc), it is difficult for robots to express their intentions to humans.

In this paper, we will show you how we tried to answer the question of how to best design zoomorphic robots considering interpretability and user experience through the implementation of certain actions. We studied how well a human can discern the intention of robot actions when we vary our robot's types of expressions that display this intent. Specifically, we focused on designing interpretable social cues for zoomorphic robots (robopet), as animal robots have been developed and investigated as companion robots in recent studies.[4][6]

Our hypothesis was that zoomorphic actions from our robopet would lead to interpretable social cues as a form of communication to humans. Further, we believed that our bark condition had a higher level of zoomorphic attributes than our bump condition, so we hypothesized that this condition would yield better results.

We conducted an exploratory study to test these hypotheses, examining the natural response from humans as they in-

Figure 1: The robot dog that was costumed for the experiment.

terpret zoomorphic robot's actions. To test this, we placed users in an isolated environment and had them interact with our robopet. We designed two different ways of expressing the same intention of the robopet, Bump and Bark, and we compared how accurately our users identified the robots intent and how quickly they acted on it. On top of that, we also observed and measured what the participants' overall experience was while interacting with the robot. Out of our two actions we tested, we hypothesized that our Bark action will perform better. We assumed the barking action displays a higher level of zoomorphism which will lead our participants to feel more connected to our robopet. If a participant feels more connected to the robopet, they should have a better overall experience and be able to understand the underlying intent with more accuracy.

In the end we found that the Bark action gave our participants a better user experience and made them react quicker, and our Bump action was more interpretable and led to a higher rate of compliance. We also learned that our participants attempted to use their prior experiences of interacting with real biological pets to help inform them of how to interact with our robopet.

2. Related Work

Companion animals are a common use case in the field of robotics. Because one of the most popular pets in the World is the dog, it makes sense that there have been many studies on robotic dogs specifically. Looking at Nadia Chernyak's work on childrens' cognitive and behavioral reactions gives us insight into one of these studies (Chernyak, Nadia 2016)[1]. Her work focuses directly on the difference between automated and controlled actions of robot dogs and how these differences can impact children differently. This is similar to our work in terms of studying interactions between humans and robotic dogs, however our work focuses on how to best display intent of robot dogs to better increase transparency and improve the overall human-robot interaction.

Looking further into other robotic dogs that exist today, our team would be remiss to not mention Sony's robot dog AIBO. Rising to fame in 1999 AIBO was a first of it's kind fully autonomous dog. However this product fell short of it's goal and was discontinued seven years after it's public launch due to a lack of sales. Looking at research studies such as the one performed by Masahiro Fujita who led AIBO's creation at SONY, we can see the studies published online tend to focus on the technical aspects of AIBO (Fujita, Masahiro 2001)[2]. Our work is trying to emulate some of Fujita's success, in terms of making a successful robopet, however there are some key differences. AIBO had an app that could be paired to each pet where users could virtually feed the dog. However there was no physical food, only a virtual screen on one's phone where the dog could be seen eating food. In the real world when this feeding occured AIBO could be seen chewing at nothing in midair with it's head tilted downwards. While this is promising, we believe a better implementation would be to use some sort of physical food that users can feed the robopet with directly. To test the best method of how to feed this robopet physically, we tested engagement levels with different levels of displayed intention when trying to cue a user to feed the pet. Because of monetary restrictions our team had to rely on a minimum value product with a barebones setup, however we believe this still gave us valuable data. Our team believes that if we can perfect the display of intent in these robot dogs the overall experience for our users will be greatly increased.

Robotic intent expression is important for most use cases of robots. It is especially important in use cases that rely on human-robot interactions, such as the integration of robots in the workplace shown in Shindev et al[10]. We as humans often take for granted the subconscious cues other humans perform while expressing intent, such as proximity zones (dangerous/threatening humans break social proximity zones and enter personal zones, friendly ones stay within the public zones), eye gaze, and gesturing (Rosen at al 2017)2[9]. Studies such as the one performed by Rosen show how when users are shown planned trajectories of robotic arms, they can determine whether or not a robot arm will collide with an object and the user can preemptively tell the robot to reroute its trajectory. Our work is similar to past research experiments in the fact that we build off previous hypotheses. Such that increasing the ability for a human to identify intent will increase a robot's efficacy. However, our work focused on a social robot rather than a robot intended for manufacturing in a workplace setting. Furthermore, our research focused specifically on robotic pets, which means our robots asked the users to perform actions for the robot rather than the robot performing actions for the user.

3. Method

3.1. Participants

For this experiment we had a target number of 10 participants (5 for condition A and 5 for condition B) where we conducted a convenience sampling by recruiting people from Cornell Tech campus. To do this we reached out to anyone we know who would be interested in participating in the study. The age ranged from 22 - 28 with a mean of 24 years old and a standard deviation of 2.54. Our participants were asked to rate their experience with robots on a scale 1 (having no robotic experience) to 10 (highly experienced with robots). The average rating was 4.7 with a standard deviation of 3.6. While there was no preference and we tried to be random, we chose to make sure we had a minimum of 2 participants from each gender. Our gender distribution was 20% Female and 80% Male. We conducted a between-participants experiment where the participants groups had a different action from the robopet.

3.2. Robot Behavior Design

3.2.1 Action A and Action B

The experiment can be compared to dog simulator games where users adopt a dog in a game and raise them by interacting with them. In these simulation games, the user is expected to accommodate the robopet by reading the social cues from the pet. We simply informed our participants to have fun with the robopet during the experiment without any further context to guide them of what to do, which is designed to be very similar to the pet simulation games.

The main goal of our study was to have this robotic dog try to communicate that it wanted to be fed. We designed two different types of action for the robopet to express this intent.

Condition A(Bump, Move, Bump): Robopet approaches the participant sitting in chair. Bump: It gently bumps into the leg of the chair or the shoes of the participant to gain the participant's attention. Move: Rotate and begin moving towards a bowl next to a written sign 'Dog Food'. Bump: Move forward and bump in to the Bowl. Turn around and stare at the participant. Continue the bump until the participant reacts.

Condition B(Bark, Move, Bark) : Robopet approaches the participant sitting in chair. Bark: Face the participant and bark to gain attention. Move:Rotate and begin moving towards a bowl next to a written sign 'Dog Food'. Bark: Stop next to the Bowl. Rotate towards the participant and bark at the participant.

Action A actively utilizes the robopet's position with the participant and physical bumping. Action B added another zoomorphic feature of a dog–barking– actively utilizing it as a cue. As a between-subjects study, each participant will only experience one of these actions.

The goal of both actions was to be signal the participant should feed the dog, so the designed behavior stopped when the participant successfully fed(or tried to feed) the robot. When the researchers informed the participant the experiment had concluded, the robopet returned to its dock. More detailed descriptions of these actions during the experiment is described in the Study Design and Study Task sections.

3.2.2 State Machines and Libraries

We had two different state machines for each action. Additionally we mapped the room out first using Turtlebot4's Lidar camera. This generated a pgm file which allowed us to send the robot to specific waypoints in the room. The robot's initial position started behind the participant.

The control architecture we used was a deliberate control architecture, the internal states are maintained until certain conditions are met, used for sensing, perception, control, and interaction. Specifically using Simultaneous Localization and Mapping (SLAM) for navigation, we outputted pet like movements. Specifically we generated a map around the room where the robopet experiment was held and distinguished specific points for the robot to perform certain actions. This was necessary as it allowed for the reproduction of experiment actions. To elaborate on the algorithms used, they followed the finite state machines below. In particular we use turtlebot4 navigation, rclpy, std msgs to process ROS images, geometry msgs for velocity of the robot, playsound to make animal noises, and gtts for text to speech. By sending messages between these nodes we were able to communicate with the robopet to simulate different interactions.

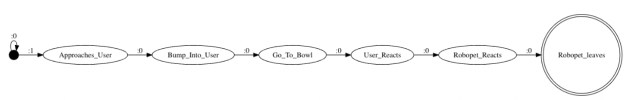

Figure 2: Action 1 Finite State Machine Diagram

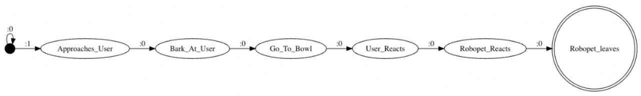

Figure 3: Action 2 Finite State Machine Diagram

```
from std_msgs.msg import String                # Used to process ROS images
from geometry_msgs.msg import Twist            # Sends velocity commands to the robot
import playsound                               # Play .mp3 file
from gtts import gTTS                          # Text-to-speech
from irobot_create_msgs.msg import InterfaceButtons
import rclpy
from rclpy.node import Node
from rclpy.qos import qos_profile_sensor_data
from turtlebot4_navigation.turtlebot4_navigator import TurtleBot4Directions, TurtleBot4Navigator
import time
```

Figure 4: Libraries used in the architecture

3.2.3 Safety Measures

Since this robot behavior design involves physical contact with the participant, we incorporated extra safety measures for the interactions. First of all, to prevent the robopet unexpectedly bumping on the participant's leg, participant was seated in a chair positioned in the middle of the room until the bumping action. One of the researchers guided the participant to the seating position. Then to initiate the robots movement, the robopet approached the participant from a docking station behind the participant. The robopet conducted one action at a time. The robopet was designed to bump the leg of the chair instead of the leg of the person. If the participant was sitting in a tricky position, the researchers tried to use manual navigation to gently bump into the participant's shoes. To prevent any unexpected physical harm, we've also asked the participant of their health concerns regarding having physical contact with a robot and notified that the experiment will be stopped immediately if it causes any discomfort from the contacts. We anticipated the robopet to not work as smoothly as expected due to technical errors. However to mitigate these errors, we were on standby just in case something went wrong in the middle of the experiment. In case of error, we had the option to continue the study task by employing the Wizard-Of-Oz method where our robopet was controlled via keyboard for all movements and each action. There was also a risk that our participants would be overly familiar with robots which made them more familiar with robot intent. To mitigate this risk we ensured that some of our participants were not familiar with robots so that our gathered data was not biased from robot familiarity.

3.3. Study Design

This research was designed as a between-subjects study because our robopet was trying to initiate being fed in both conditions (Bark and Bump). If our participants were to experience both trials, they will very likely complete the second trial much faster and with greater accuracy due to being familiar with the experiment, which would have biased our data. Each participant interacted with one type of robot action out of two conditions (Bump-Move-Bump, Bark-Move-Bark). The experiment was human-focused as we gathered insights and metrics based on the participant's reactions, we were not testing the robots ability to perform its own actions. There were 4 metrics we aimed to measure: 2 objective metrics: compliance and time to react in seconds, as well as 2 subjective metrics: user experience and perceived interpretability of the robot. Table 1 elaborates on these dependent variables in detail and Figure 5 shows the factorial design of this study.

In terms of counterbalancing, we blindfolded the participants so they would not make any judgements before the experiment began. We gave them no information besides telling them they can get out of their chair for interactions with the robopet during this experiment. This tabula rasa approach helps to unbias our experiment as much as possible, so we can see the true reaction of our participants in a simulated real world scenario. We also included a leash as a fake task so there would be more of a chance for non-compliance.

Compliance	whether the participant successfully interpreted the intention and carried out a correct task
Time to React (secs)	time in seconds from the moment they encounter the robopet and to initiate a task after they interpret the robopet's intention
User Experience (Self Reported scale: 1-5)	How did the participant feel about the overall experiment. Did they enjoy interacting with the robopet? Self-reported in a post experiment survey at 1-5
Interpretability (Self Reported scale: 1-5)	How well did the participant feel they could interpret the intent of the dog? Did they understand what the dog was requesting? Self-reported in a post experiment survey at 1-5

Table 1: Dependent Variables

3.4. Study Task

While we didn't provide specific guidelines to the participants for what to do during the experiment until the post-experiement debrief, they were expected to i) interpret the robopet's intention and ii) carry out a task according to their

Factorial Design (Between Subjects)

	Compliance: Fed the Robopet?	Time to React (in seconds)	Satisfaction Level (Self-reported)	Interpretability Level (Self-reported)
Action A (Bump-Move-Bump)				
Action B (Bark-Move-Bark)				

Figure 5: Factorial Design(Between Subjects)

interpretation.

In our case, the robopet's intention was to gain the human's attention and get food from the human. From the human participant's point of view, their correct task was to feed the robopet.

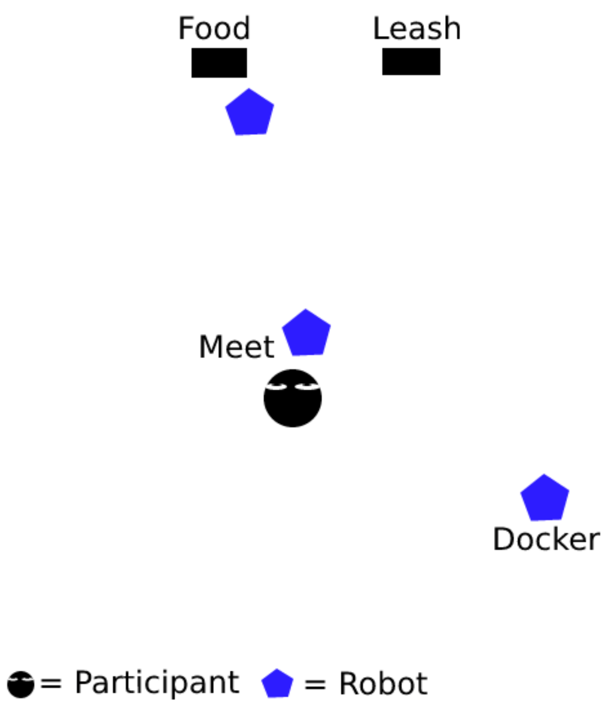

Figure 6: Experiment Space Environment

Figure 6 depicts the space environment where the experiment was conducted. Each participant began the experiment in a seated position in the middle of the room. At this point, the participant had not encountered the robopet at all. He/she was blindfolded in a safe way when guided to the position so they didn't have any expectations of what kind of robot they will be interacting with. The robopet approaches from a docker behind the participant and made the first encounter. As it carried out a sequence of actions, it navigated towards the 'Food' area of the room. There were two props in the room in plain sight of the participant. One, a food area with an empty bowl and a bag of candies with a 'dog food' sign on it. Two, a walking area with a belt with a 'dog leash' sign on it. Even though there were no instructions on what to do during the experiment, we notified the participant to feel free to leave seating position so they understood they can approach these areas and physically use the props. The leash was a red herring so the participants would have more than one option of an action to take. If it was only the bowl in the room, it would be fairly obvious that they were supposed to use the bowl somehow. This way, if the participant goes for the leash their trial can be deemed as a non-compliant trial. This red herring creates a gamification aspect to our study, for now the participants can make a wrong choice.

Figure 7: Actual experiment environment with participants

During the experiment, there were several scenarios where the participant engaged and responded to the robot in an expected way. Meaning when the robopet's intention was properly interpreted by the human; the human had a range of freedom to carry out the task (to feed the dog) in any natural and appealing way for themselves. For example, they could 'feed' the robopet in any way they thought was appropriate. They were also free to use the leash if they so chose (even though this would render their trial a failure). Also from the robopet's point of view, it repeated its action within each design to make the cue more obvious and moved on after an appropriate amount of time. An example of this would be if the participant did not respond in an expected way after it repeats a certain cue multiple times, the robopet would move on to the next action. After the action was completed, the robopet went back to the docking station. For adopting more flexible scenarios like this, one of the researchers was in the same room overlooking and recording the entire experiment. The timing of each action was measured by this researcher after the experiment by analyzing the video footage. The researchers notified the participant when everything was completed and then handed out a written survey form for each participant to complete right after the study.

3.5. Data Collection

A written survey was conducted at the end of the experiment. It included some questions on demographic information, overall user experience with the robot(Satisfaction metric), level of diffucuty for interpretation(Interpretability metric), and questions on their guess of robot's intention and their reasoning behind it. After the debrief where we revealed the correct intention of the robot, and they moved onto the last question of the written survey: providing their opinion on what could have been improved in the robot's actions to make it easier for them to understand that the robot wanted to be fed.

On top of that, one of our researchers in the same room gathered other human-focused data. For example, the researcher measured time in seconds from when the participant first encountered and noticed the robot to when they initiated the action of feeding(e.g. grabbing the bag of food). The researcher also recorded whether the participant successfully carried out the task of feeding the dog or not. Ideally, this data was collected automatically by the robot with a camera and face recognition libraries and captive sensors in the future. However in this study, we recorded all our results in a spreadsheet to calculate the data and graph appropriately.

Moreover, we recorded the entire experiment to confirm the data that the researchers collected during the experiment.

4. Evaluation

4.1. Experimental Metrics

We had four overall metrics in this study, two objective metrics: Compliance, and Time to React; and two subjective metrics: Interpretability and User Experience.

Our subjective measurements were gathered through a post-experiment survey. This included a question on how interpretable each action was, given the correct answer on a scale of 1(Not Interpretable at all) to 5(Very Easily Interpretable), as well as what their self reported experience was on a scale of 1 (Not enjoyable) to 5 (highly enjoyable)

Our objective measurements were analyzed through data gathered during the experiment. Time to React: How long did the user take from the first attention gathering action (bump/bark) to them actually getting out of the chair, walking over to the bowl, and putting food in the bowl? Compliance: Did the participant go straight for the bowl and did they put food in the bowl? These metrics were found by analyzing the video footage and through researcher notes during the experiment.

4.2. Data Analysis

We have two independent variables in this experiment and four dependent variables so we analyzed all our results in graphs for a direct comparison, seen in Figure 8-11. We evaluated all our data by graphing our survey results in a bar graph so we could easily see a visual representation of all of our user surveys. We also graphed our success rate for each participant to see how the specific condition they were in affected their performance ability. Finally we looked at our data on timing; cross referencing our bar graphs to see how the variance on time relates to our users' ability to complete the desired task and overall self-reported score of ability to perceive the robopet's intent. We analyzed all these results to see what the average, variance, and standard deviation is for our success/failure rates for both conditions and saw how the bark/bump affected our users' ability to perceive intent. The independent variables in this experiment were two different sequence of actions involving bumping, staring, moving, and barking. In action the presence of the robot bump or the barking action. The dependent variables were the interpretability of these actions from the human's point of view, whether they had a positive experience, data of whether or not the human performed the desired action, as well as length of time taken to response to the robopet.

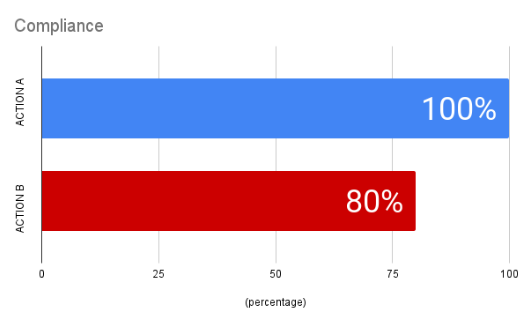

Figure 8: Result of Compliance Metric

5. Results

Our hypothesis was that zoomorphic actions from our robopet would lead to interpretable social cues as a form of communication to humans. Further, we believed that our bark condition had a higher level of zoomorphic attributes than our bump condition, so we hypothesized that this condition would yield better results.

We were able to confirm our hypothesis that a robopet imitating the look and the common actions of a real dog

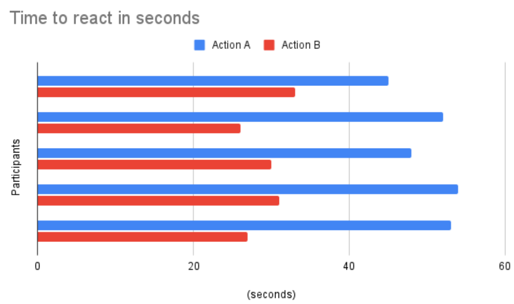

Figure 9: Result of Time to React Metric

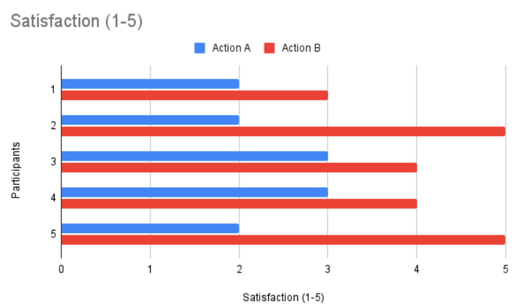

Figure 10: Result of Satisfaction Metric

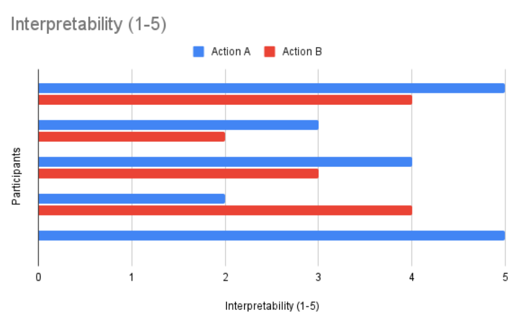

Figure 11: Result of Interpretabilty Metric

can make interpretable social cues in Human-Robot Interaction in a way that affects user performance and experience. Looking at previous studies, we expected the barking feature to increase our users' ability to discern the robopet's intent. However, our hypothesis wasn't confirmed on all fronts. We saw that the Bark condition led to a higher overall rate of user satisfaction with our robopet, as well as a shorter time to react. We also saw that the Bump condition led to a higher rate of compliance and interpretability.

For the bark condition, the Compliance average rate = 80%, with a standard deviation = 0.447 and variance = 0.2. The Time to React (sec) had a mean = 29.4 sec, std = 2.881, var = 8.3. The User Experience rating had a mean = 4.2, std = 0.837, var = 0.7. The Interpretability rating had a mean = 3, std = 1, var = 1.

For the bump condition, The Compliance average = 100%, std = 0, var = 0. Time to React (sec) had a mean = 50.4 sec, std = 3.751, var = 14.3. The User Experience rating had a mean = 2.4, std = 0.548, var = 0.3. The Interpretability rating had a mean = 3.8, std = 1.3, var = 1.7.

Our analysis is that because the Bark action has a higher level of zoomorphic attributes than the Bump action, this led to a slight novelty effect on our participants. Our participants were more eager to get up out of their chair and interact with the robopet than they were in the Bump condition. This eagerness however, did not always lead to the correct task being completed; it led to participants being slightly more confused on what task to complete. The Bump condition, while not as much fun (as supported by experience ratings from our participants), led our users to think more carefully about how to act. Those participants in condition A (Bump) thought longer about how to react, and this led to a higher rate of interpretability as well as a higher rate of compliance.

While trying to answer the question of which zoomorphic action is best to design into a robotic companion pet, the answer is slightly unclear. Out of these two conditions, they both had their benefits and drawbacks. Our analysis is that a perfect robopet would have a combination of both actions; a bark to entice the user and make it more fun, with a bump to make it more clear what the objective is. In fact, two of the participants who experienced Action A, which doesn't involve barking, explicitly pointed out in the post-survey that it could have been easier to interpret the robopet if it had a barking (audio) cue. For example, one mentioned it should be clearer sign for 'need' or 'satisfaction' if the robopet had barked before or right after the feeding. Without the barking sound, the participant was confused if the dog was satisfied after he fed the dog.

Some more interesting observations from the experiment come from the participants' direct perception of the robot as a real dog when it had limitations on physical resemblance. For example, when carrying out the feeding task, two participants actively looked for a way to make them 'eat' the food. Even when they knew robots don't necessarily consume real food, they peeled off the package or looked for its mouth. Few expressed the confusion from 'where and how' to give the food when the robot's neck seemed fixed in position, preventing to reach the bowl on the ground. While we focused on the high-level task of 'giving the food prop to the robot' in any ways, participants seemed to actually care a lot about how this interaction happens in comparison to a real dog with a real mouth. We expected the user to react somewhat similar to how they would react to some dogs but didn't expect the physical features and capabilities would affect the response so much.

Also, we realized the downside of conducting an open action experiment where we don't give the participants any guidance is that the participant would guess the goal of the study to be observe as much as interaction possible with the robot, so they pushed themselves to do more random things even though they did not perceive any cues from the robot. For example, almost half of the participants, regardless of the independent variables, wanted to use the leash prop as well even though there were no cues provided to prompt that response.

6. Discussion & Future Work

Our study goals were to analyze how humans naturally react to zoomorphic robots when these robots show varying levels of zoomorphism to display their underlying intentions and actions. Through this study, we could see how each action affected the overall user experience and success rate of feeding the robopet at the appropriate time. By performing a purely human focused experiment, we were able to see how our independent variables affected our users' experience with the robot. This approach differs from previous research studies that focus on a more technical side of testing like testing different functionality such as recognition of specific users. Our study also builds off of previous work that focuses on anthropomorphic intent and how that affects efficacy in a human robot interaction[3].

The first part of our hypothesis is validated by previous works. Our study adds to a list of previous research studies, like Eric Rosen's work, showing that the display of intent is a crucial aspect of human robot interaction. However overall, this experiment can not be deemed a full success. While our results did support our theory that zoomorphic actions can be a successful way to express intent; our results also showed that there was no clear best action out of the two. We predicted that the bark condition would be best; and even though the bark condition led to quicker reaction times and a higher user experience, this condition also had lower rates of compliance and interpretability. While the bump condition had higher rates of compliance and interpretability, this condition had lower rates of reaction times and user experience. The best action would be some combination of both, as to maximize all four metrics. In future works, we can improve upon our study by adopting different combinations of zoomorphic actions or adopting robotic and anthropomorphic features such as lighting, speaking or grabbing. We would also like to compare these features to a condition with no zoomorphic features whatsoever. This can give us a more clear control group to compare our results to.

Furthermore, we learned that many participants leaned on prior interactions with pets when interacting with a zoomorphic robot. As such even when they misinterpreted some of our robotpet's actions they still completed the desired task. Knowing this in the future we would plan to generate more robot interactions as well as have more devices for the participants to use in the experiment. Also the experiment can be conducted with more guidelines and instructions for the participants in the future, as some of them didn't know they could stand instead of sit in the chair when interacting with the robopet.

We did have some limitations to our study which can all be improved upon in future work. Ideally our sample size would have been 25 per condition, and we were only able to recruit 5 participants per condition. Due to monetary constraints, we had to rely on a minimum value product which is inherently less interactive. In the future we could have a dog food bowl that has a weight sensor in it so it can send a command to the robopet to signal a completed task. This could trigger a completion gesture from our robopet to give our users a higher feeling of connection to our robopet.

Overall even though this experiment was a full success, we still gained valuable information. We found that zoomorphic features do indeed affect user ability to decipher intent of a robot. While we did not find a clear best action to use to display this intent, we showed how Bark can be very engaging to a user and how Bumping can show clear intent. In the field of HRI, future researchers can build upon this work by finding a combination of different features, or by using the actions we studied, to build a more reliable and communicable robot companion. Once the perfect combination of features has been figured out, a true integration of robots into our human world becomes a much more feasible concept.

7. Team Member Contributions

7.1. Technical Components

Programming - Kenneth Alvarez, Sam Willenson, Soul Choi

7.2. Writing Components

Abstract - Kenneth Alvarez, Sam Willenson, Soul Choi Introduction - Kenneth Alvarez, Sam Willenson, Soul Choi Related Work - Kenneth Alvarez, Sam Willenson, Soul Choi Method-Participants - Kenneth Alvarez, Sam Willenson, Soul Choi Method-Robot Behavior Design - Kenneth Alvarez, Sam Willenson, Soul Choi Method-Study Design - Kenneth Alvarez, Sam Willenson, Soul Choi Method-Study Task - Kenneth Alvarez, Sam Willenson, Soul Choi Method-Data Collection - Kenneth Alvarez, Sam Willenson, Soul Choi Evaluation-Experimental Design - Kenneth Alvarez, Sam Willenson, Soul Choi Evaluation-Data Analysis - Kenneth Alvarez, Sam Willenson, Soul Choi Results - Kenneth Alvarez, Sam Willenson, Soul Choi Discussion - Kenneth Alvarez, Sam Willenson, Soul Choi Future Work - Kenneth Alvarez, Sam Willenson, Soul Choi

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A. Appendix

A.1. Video Demonstrations

Action A https://drive.google.com/file/d/1ggT6X5xqGQtCnZ68jP2UDTdJT8vSibaH/view?usp=sharing

Action B https://drive.google.com/file/d/1SQHl5v8aDOsKkDoJHq-C22_ffCrSwTCw/view?usp=sharing

A.2. Consent & Demographic Form

After the goal of the study was verbally explained to the participant in plain English by one of the researchers, the participant signed the consent and provided their information on full name, gender, age, experience level with Robot, and whether they have experience with a real dog as a pet.

Study Participant Consent and Survey

Participation Consent: (sign)

Participant Name:

Gender:

Age:

Experience with Robot (1:No Experience - 10: High Expertise):

Have you had a dog as a pet?(Yes/No):

Figure 12: Form to Collect Participation Consent and Demographic Information.

A.3. Study Script

The study script provides a word-for-word narration of what the interviewer states during the study sessions.

HRI Experiment Script

Researcher: Thank you for agreeing to participate in this research experiment! The goal of this experiment is to observe how humans naturally react to robot-pets.
In this study, you will be physically interacting with our robot. Let us know if you have a health condition that might concern you for the If at any point of the study may the robot cause any discomfort or pain from its actions, please let us know. We will immediately stop the experiment and accommodate your situation. Do you understand?

Participant: I understand. I don't have any health concerns.

Researcher: During the experiment we require your complete, undistracted attention. So we ask that you follow these instructions carefully.

Participant: Yes I will follow

Researcher: You may not open other applications on your computer, chat with other students, or engage in other distracting activities, such as using your cell phones or headphones, reading books, etc.

Participant: *Puts items away*

Researcher: Lastly, this experiment will be videotaped for the purpose of research. The videos might be shared publically in class is that okay?

Researcher: To give you some background you will have an interaction with a robot. React the way you think you should. The entire experiment should take less than 10 minutes. So if you could sit here and we will conduct the experiment shortly.

Participant: *Sits down*

EXPERIMENT STARTS

Researcher: Thank you for your participation. The experiment has ended! If you could please fill out this form.

Researcher: *Hands them the form*

Figure 13: Script used at the beginning of the study to onboard the participant

A.4. Post-Study Surveys

Study Participant Consent and Survey

Participation Consent: (sign)

Participant Name:

Gender:

Age:

Experience with Robot (1:No Experience - 10: High Expertise):

Have you had a dog as a pet?:

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Overall I had a good experience with the dog					
It was clear and easy to understand the robot's intention					
What do you think the robot wanted to communicate?					
Regarding your answer above, what indicated the robot's intention?					
(After debrief) Are there any improvements that you feel we could make to the robot?					

Figure 14: Post-study Survey