An Observation of Behavioral Changes of Indoor Dogs in Response to Caring Behavior by Humanoid Robots

Can Dogs and Robots Be Companions?

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Abstract: The aim of our research is to build good relationships between pets and robots at home. We aim to promote of positive interaction between pets and robots. Recently, robots have been become popular with the general populace. There is a lot of research in human-robot interaction. We pay attention to pets that live in houses with humans. It is required for pets to like robots for positive interactions between pets and robots to exist. In this paper, we examine that 1) a robot can take care of dog, and 2) dogs and robots can be companion by caring behavior of robots toward dogs. In our experiment, we used two robots. One of the robots takes care of a dog, while the other does not. We observed which robot the dog chooses to interact with and had seventeen dogs participate in this study. We performed this statistical test to judge whether the dogs treated the robots with any significant differences.

1 INTRODUCTION

Recently, communication robots like Pepper (Aldenaran, 2015) have become popular in the everyday household. Existing studies have been exploring the possibility of coexistence between humans and robots in a human-robot interaction field. The coexistence of pets and robots that live in the same, however, has not yet been explored. The objective of this study is to disclose behavioral guidelines for robots living with pets. We are therefore researching Pet-Robot Interaction (PRIN) (Figure 1). There are two main goals of PRIN: 1) promotion of positive interaction and 2) prevention of negative interaction. The positive interaction represents the good relationships between pets and robots. Examples of such positive interactions include robots becoming pet playmates instead of humans (Figure 2 left), robots feeding pets (Figure 2 right), robots training pets, and robots aiding in the care of the pets of the elderly. The negative interactions represent the bad relationships of pets and robots. Examples of such negative interactions include pets that are surprised by the movement of robots and pets disturbing the actions of robots. It is important to disclose the factors that promote positive interactions and prevent negative interactions for good relationships between pets and robots to develop through various situations at home.

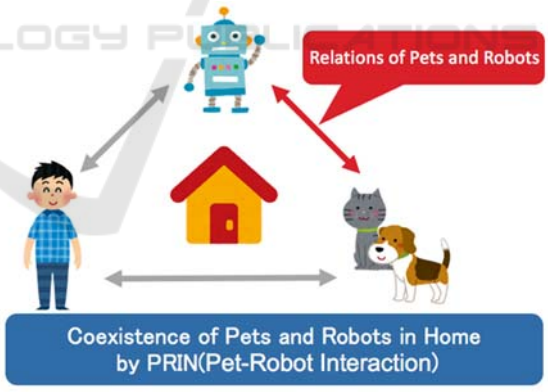

Figure 1: Image of PRIN.

The study focused on two main research questions:
RQ1 : Can robots take care of dogs?
RQ2 : Can dogs and robots be companion by caring behavior of robots toward dogs?

In this study, we provided two conditions of robots being around pets. The first was robots performing caring behaviors toward pets, and the second was robots performing no caring behaviors toward pets involved in the study. As a result, caring

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behaviors of robots influenced the behavior of the dogs.

In Section 2 of this paper, we describe the implementation of movement of caring-behavior robots and the preparations made for the experiment. Section 3 discusses the procedures involved in the experimental observation of behavioral changes in dogs in response to caring-behavior robots. We describe the results of the experiment in Section 4. Section 5 breaks down a discussion of the experiment, and next, Section 6 describes research related to our experiment, such as Human-Robot interaction and animal behavior. Lastly, Section 7 summarizes our research with a conclusion.

Figure 2: The dog on the left is running after the ball thrown by a robot. The dog on the right is eating food that was given to it by robots.

2 THE METHODOLOGY OF CARING BAHAVIOR OF HUMANS AND HUMANOID ROBOTS TOWARD DOGS

In Section 2, we explore the difference between when a human take care of a dog and when the robot takes care of a dog. In 2.1, we will observe the care of dogs by humans, and in 2.2, we will describe parts of the preparations undertaken for the experiment, including the environment of the room, the implementation of movement patterns of caring-bahavior robots, and the result evaluation method.

2.1 Caring Behaviour of Humans toward Dogs

Currently, dog owners are used to taking care of their dogs all the time. Examples of cares given to dogs include feeding, acting as a playmate, toilet cleaning, taking for walks, brushing, bathing, clipping nails and hair, etc. We think the burden can be reduced for the owner by humanoid robots that can care for dogs. In addition, we think that caring-behavior robot will improve the dog's quality of life. We will focus on two aspects of the experiment: "playmate" (playing ball) and "feeding".

First, we observed the behaviour of each dog when humans took care of it. Table 1 shows the details of the participant dogs during this part of the trial.

§1 Playmate (Playing Ball)

The experimenter threw the ball, and we observed whether the dogs held the ball in their mouths. This was repeated five times. As a result, nine dogs held the ball in their mouths five times each, one dog held the ball in its mouth one time, and seven dogs didn't hold the ball in their mouths at all. Through this part of the trial, it became clear that there are dogs that play ball and dogs that do not play ball.

§2 Feeding

Dogs B and E were unable to concentrate on this part of the experiment. The experimenter fed using tray the other dogs without trouble. We observed whether the dogs ate. This was repeated five times. As a result, fifteen dogs ate the human-introduced bait five times each.

Table 1: Participant dogs.

ID	Breed	Sex	Age (in years)
A	Shih Tzu	F	9
B	Pomeranian	F	5
C	Mix	M	0.5
D	Chihuahua	M	4
E	Mix	F	0.5
F	Mix	F	0.5
G	Mix	F	0.5
H	Toy Poodle	M	4
I	Mix	M	3
J	Mix	F	0.5
K	Chihuahua	M	6
L	Mix	F	3
M	Toy Poodle	M	5
N	Mix	M	4
O	Chihuahua	F	6
P	Toy Poodle	F	3
Q	Toy Poodle	F	7

2.2 Caring Behaviour of Humanoid Robots for Dogs

We observed the behaviour of the dogs when humans took care of them in 2.1. Next, we will examine the behaviour of the dogs when humanoid robots take

care of them. Two robots were used in the experiment. We defined one of the robots taking care of a dogs as the “care robot”, and the other robot was referred to as the “non-care robot”. In this experiment, we observed behavioral changes in the dogs in response to the caring behavior of the care robot.

2.3 Preparation of Experimentation

In the experiment using the care-robot and non-care robot, we will describe the implementation of movement patterns of the caring-behavior robots in 2.3.1. The environment of the room is described in 2.3.2.

2.3.1 Implementation of Care Robot

This experiment involves the humanoid robot Pepper (made by ALDEBARAN). Pepper’s movement patterns were installed using Choregraphe 2.4.3 software. The two types of care behavior involved ("playmate" and "feeding") required the implementation of human-like movement. The following information is a detailed account of the behavior of the robot.

§1 Playmate (Playing Ball)

The robot needed to throw the ball to play with each dog. The motion of the robot was divided into the following three actions for it to throw the ball.
STEP 1: The palm of the robot faced upward and robot held the ball with its fingers bent, and the arm bent at the elbow.
STEP 2: The robot swung the arm down while holding the ball.
STEP 3: The robot threw the ball by opening the fingers while swinging the arm up.
Figure 3 below shows the steps of the robot throwing the ball.

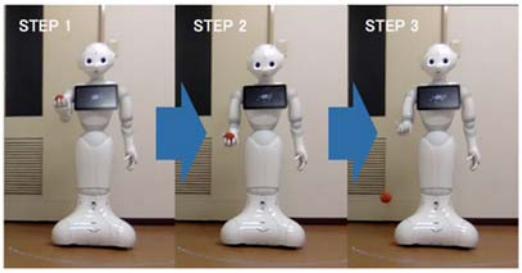

Figure 3: The robot throws a ball.

§2 Feeding

We prepared a bait tray by tying a string to the paper plate for the robot to the lift and lower the bait (Figure 4). The robot fed the dog by placing the plate on the floor using the string secured to the bait tray. We use the bait that each dog eats normally.

Figure 4: Bait tray with a string to it.

The feeding motion of the robot was divided into the following two actions.
STEP 1: The string of the bait tray was put in the palm of the robot’s hand.
STEP 2: The robot put the bait tray on the floor by bending at the waist.
Figure 5 below shows the steps of the robot feeding the dog.

Figure 5: The robot puts the tray on the floor.

2.3.2 Experiment Room

The room was large enough to place the care robot and non-care robot inside and a dog could move freely. In the room, there were chairs and tables. Figure 6 is a sketch of the room in which the experiment took place. Diagonal lines show the furniture. Smiling faces represent the position of the robots. The two robots faced the center of the room.

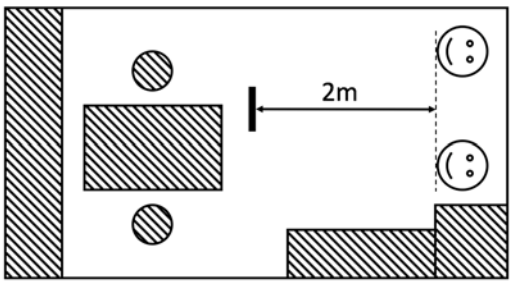

Figure 6: Sketch of the room.

3 EXPERIMENT

The experiment was to explore the non-care robot and care robot actions implemented in Section 2 and observe the dog's behavioural changes following the care robot's actions toward the dogs. After the care robot performed a care action, the tray containing the bait was placed in front of the two robots. One dogs at a time was released from a distance of 2 m. from the robot, and we observed whether the dogs ate the food in front of either robot.

In order from the dog to determine the difference between the care robot and non-care robot, the dogs distinguished between the yellow and blue (Neitz, 1989). One of the two robots was dressed in the yellow outfit, and the other wore blue clothes. The color of clothing was replaced for each test dog.

The experimenter changed the position of the robot that took over the caring care behavior for each seventeen dogs. The following describes the details of the procedure for each caring behavior.

3.1 Playmate (Paying Ball)

Experiments were conducted in the following conditions and procedures for all seventeen participant dogs.

3.1.1 Conditions

The playmate phase involved the two conditions below.

Condition 1: The care robot played ball with the dog.

Condition 2: The non-care robot didn't play ball with the dog.

3.1.2 Procedures

First, the care-robot, non-care robot, and a dog were placed into the experiment room (2.2.2). The experiment followed four steps for each participant dog (Figure 7).

STEP 1: Care robot threw the ball. Then we observed whether the participant dogs held the ball in its mouth. This was repeated 10 times.

STEP 2: Put the trays of bait in front of the two robots.

STEP 3: We observed which tray the dog ate from first. This was repeated 5 times.

STEP 4: The experimenter swapped the position of the care robot and non-care robot manually in front of the eyes of a dog.

STEP 5: The Tray of bait were put in front of the two robots. We then observed which tray the dog ate from first. This was repeated 5 times.

Figure 7: The procedures of the experiment.

3.2 Feeding

Experiments were conducted in the following conditions and procedures for fifteen of the participant dogs. Exclude Dogs B and E because they couldn't concentrate on this part of the experiment. Experiments were conducted following the conditions and procedures described below.

3.2.1 Conditions

Two conditions of the feeding act are described below.

Condition 1: The care robot feed the dog.

Condition 2: The non- care robot didn't feed the dog.

3.2.2 Procedures

Care robot, non-care robot, and a dog were placed the experiment room (2.2.2). The experiment followed the four steps below for each participant dog.

STEP 1: Care-robot fed the dog. This was repeated 10 times.

STEP 2: Put the trays of bait in front of the two robots.

STEP 3: We observed which tray the dog ate from first. This was repeated 5 times.

STEP 4: The experimenter swapped the position of the care robot and non-care robot manually in front of the eyes of a dog.

STEP 5: The Tray of bait were put in front of the two robots. We then observed which tray the dog ate from first. This was repeated 5 times.

4 RESULTS

4.1 Playmate (Paying Ball)

In Step 1of the playmate experimental procedure, the care robot threw the ball 10 times. The dogs involved in the experiment are shown in Table 1, and after the experiments, the dogs were split into two groups. The number of the participant dogs that held the ball in their mouths is nine [C, E, F, G, H, J, L, N, and P], and this occurred an average of 9.88 times.

The number of the participant dogs that held the ball in their mouths is eight [A, B, D, I, K, M, O, and Q], and this occurred an average of 0.375 times.

In the following figures, we refer to the dogs that held the ball in their mouths as "dogs that play ball with robots," and we refer to the dogs group less than five time that held the ball in their mouths as "dogs that do not play ball with robots."

The experiment disclosed that care robot can play the ball with dogs. And, it is equal human fed.

The bait trays were placed in front of the two robots in experimental procedure Steps 3 and 5. We observed which tray the dog ate from first 10 times each for the two groups previously mentioned. The results are shown in Figures 8 and 9. The group, "dogs that play ball with robots," (nine dogs) chose to eat the food an average of 6.22 times when it was placed in front of care robot and 3.66 times when placed before non-care robot (Figure 8). Dog P did not eat the food of either robot one time out of the ten; however, she ate the bait the other nine times. The group, "dogs that do not play ball with robots," (eight dogs) chose to eat the food an average of 4.125 times when it was placed before care robot and 5.75 times when the tray was put in front of non-care robot (Figure 9). Dog D refused to eat the food in front of both robots once out of ten times; however, she, too, ate the bait the other nine times.

We calculated the number of selected times "dogs that play ball with robots" first ate from each robot. The result is P = 0.000194. The calculation of the t-test showed that the behavioral changes of the dogs are statistically significant. The study notes that "dogs that play ball with robots" chose care robot more times than non-care robot.

We calculated the number of selected times "dogs that do not play ball with robots" first ate from each robot. The result is P = 0.0164. The calculation of the t-test showed that the behavioral changes of the dogs are statistically significant. The study suggests that "dogs that do not play ball with robots" chose non-care robot more times than care robot.

The video of the experiment is in https://www.youtube.com/channel/UC8Zri5sVRCUw1kpesuNByVQ.

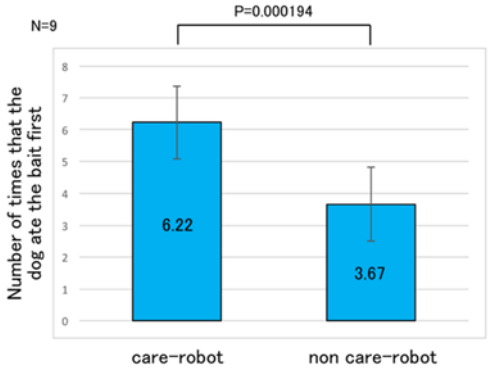

Figure 8: The number of times "dogs that play ball with robots" first ate the bait in front of each robot after playing ball.

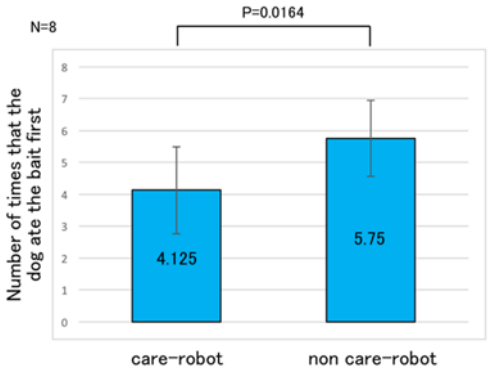

Figure 9: The number of selected times “dogs that do not play ball with robots” first ate the bait in front of each robot after playing ball.

4.2 Feeding

In experimental procedure Step 1, the care robot fed each dog 10 times. The fifteen dogs ate the bait an average of 7.33 times. The trays were placed in front of the two robots in experimental procedure Steps 3 and 5. The average results are different from the frequency of times the human fed the dogs. We summarize that robots can feed dogs, but the frequency of times the dogs ate are not equal.

We observed which tray of food the dog ate first 10 times. The tray the dogs chose averaged 6 times for the care robot and 4 times for the non-care robot (Figure 10).

We calculated the number of selected times a robot was chosen by the dogs. The result is P = 0.002224. The calculation of the t-test showed that these behavioral changes of the dogs are statistically significant. The results show that dogs chose care robot more often than non-care robot.

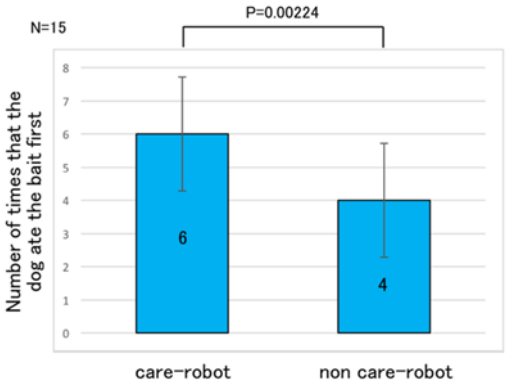

Figure 10: The number of times a dog first selected each robot after the first feeding.

5 DISCUSSION

5.1 Feeding

“Dogs that play ball with robots” [C, E, F, G, H, J, L, N, and P] chose the care robot an average of 5.875 times and non-care robot an average of 4.125 times (Figure 11). Note that “dogs that do not play ball with robots” [A, B, D, I, K, M, O, and Q] chose the care robot an average 6.125 times and chose non-care robot an average of 3.857 times (Figure 12).

In both groups, the dogs chose care robot more often than non-care robot. In particular, there is a significant difference between the choices of care robot and non-core robot in “dogs that do not play ball with robots.” The result is P = 0.002224. Results show that “dogs that play ball with robots” chose eating from care robot more often.

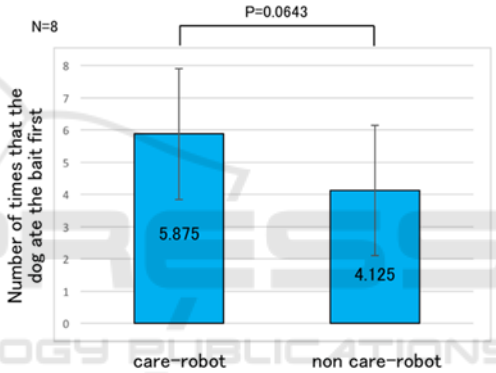

Figure 11: The number of times “dogs that play ball with robots” first ate the bait in front of each robot after feeding.

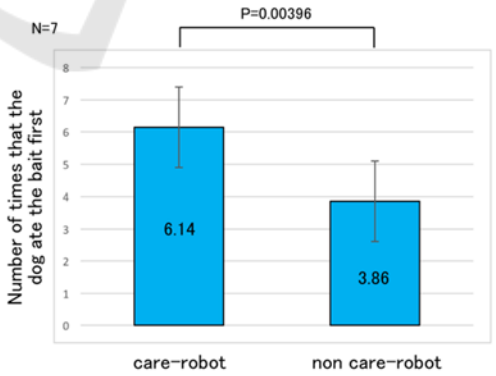

Figure 12: The number of selected times “dogs that do not play ball with robots” first ate the bait in front of each robot after feeding.

5.2 Promotion of Positive Interaction

Behavioral guidelines of robots in order to promote the positive interaction of dogs and robots are:

1) The robot can play ball with "dogs that play ball with robots."

2) The robot can feed "dogs that do not play ball with robots."

5.3 Prevention of Negative Interaction

In the playing-ball experiment, "dogs that do not play ball with robots" chose the non-care robot in some cases. It is considered that "dogs that do not play ball with robots" have a negative impression of the care robot. Some dogs interacted negatively with the robot, but other dogs interacted positively with the same robot.

We observed a negative interaction in feeding experiments. A behavior of the robot surprised the dog, and the dog ran away from robot because the robot moved suddenly (Figure 13). Behavioral guidelines of robots hope to prevent future negative interaction such as this. The most noted guideline is:
1) The robot needs to move slowly when the dog is near.

Figure 13: The dog was surprised and ran away from robot.

6 RELATED RESEARCHES

The human-robot interaction field has conducted various studies related to the spread of the robots in homes: medication management for the elderly at home (Prakash, 2013), dog-inspired hearing robots lead participants to sound sources (Koay, 2013), social robots elicit increased learning in children (Kennedy, 2015). In relationships between humans and dogs, dogs avoid people who behave negatively toward their owner (Chijiiwa, 2015), dogs like humans who give food to other humans (Kundey, 2011), and there is the oxytocin-gaze positive loop between a human and dog when they look each other (Nagasawa, 2015).

In animal-computer interaction, Zeagler et al. observed a dog's touchscreen interactions (Zeagler, 2014). They used yellow and blue circles screen, and dogs touched the circles with their nose. This has been used to note that dogs can differentiate between yellow and blue (Neitz, 1989). Mancine et al. proposed a canine cancer detection system (Mancini, 2015). Baskin et al. observed that dogs can play on tablets (Baskin, 2015). Robots affected the dogs' performance by Lakatos et al. (Lakatos, 2014) Many of these studies observe animal behavior in a system.

In this study, we aimed to build good relationships between pets and robots at home. We observed dog behavioral reactions to two types of robots (care robot and non-care robot). For the dissemination of robots to the everyday home, we need examine not only human-robot interaction, but also pet-robot interaction. Positive pet-robot interaction must also consider the characteristics of each pet and the relationship between pet and owner.

7 CONCLUSIONS

This study was conducted as an experiment for possible the coexistence of pets and robots in the home. Both a human and a robot took care of the dogs. The behavior of the dog toward the human, care robot and, non-care robot was closely monitored. This study taught us that robots can take care of a dog instead of a human. We also discovered that care behavior of a robot influences the behavior of the dog. In the experiment, we used two robots (care robot and non-care robot) and placed bait in front of them. We observed which bait the dog ate first. In the experiment of playing ball, there were two groups: "dogs that play ball with robots," and "dogs that do not play ball with robots." Different behavior of the dogs toward care robot and non-care robot showed it is better for a robot to throw a ball to promote positive interaction. In the feeding experiment, we noted different behaviors of dogs between care robot and non-care robot. It is better for a robot to feed the dogs to prevent negative interactions. From each dog's reaction to sudden movements during the experiment, it is best if the robot moves slowly when the dog is near.

For future experiments, increasing the participating number of dogs would be useful. We will conduct various versions of this experiment to explore other questions. For example, can a dog learn through playing with the robot? Is the behavior of a dog different depending on the relationship between

the owner and the robot? Using the results of the this study, adapting algorithm of the robot's behavior to dog, researches on home robot will advance.

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