Gap between Owner's Perceptions and Dog's Behaviors Toward the Same Physical Agents: Using a Dog-like Speaker and a Humanoid Robot

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ABSTRACT

Dogs are often considered as humans' oldest friends. The relationship between people and dogs (wherein they are regarded as family members in the home) is well-studied. Since social agents have recently become a part of family life, a new field of research has been introduced that is centered on the human-agent and dog-agent relationships. Hence, in this study, to investigate how social agents are perceived by dog owners and dogs, we employed existing communication agents such as smart speakers and conducted two experiments; the first one investigated dog owners' impression toward the agents in agent-owner interaction and the second one investigated dog's behavior in front of the agents during owner's speaking to the agents and the agents' speaking to the dogs. Furthermore, we statistically analyzed the results of thirty-three dog-owners and twenty-one dogs. The results obtained from the GODSPEED questionnaire analysis indicate that regarding aspects such as anthropomorphism, animacy, likability, and perceived intelligence, the dog-like smart speaker is significantly worse than the educational humanoid robots NAO and Pepper. Regarding aspects such as animacy, likability, and perceived intelligence, the dog-like smart speaker has a significantly lower rating than Google Home, and it has a lower rating than Pepper with respect to perceived safety. However, in the case of canine behavioral analysis, the percentage of individuals who engaged in social behaviors (such as sniffing the rear) in response to the dog-like smart speaker is found to be significantly higher than that for the other agents. Hence, although this study is an exploratory experiment in terms of subject limitations and determination of behavioral indicators, it is the first step towards bridging the gap between owners' and dogs' perceptions of an agent's sociality while employing the same physical agents.

CCS CONCEPTS

• **Human-centered computing** → **Empirical studies in HCI**; **Empirical studies in interaction design**; **HCI design and evaluation methods**.

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Figure 1: Google Home

Figure 2: NAO

Figure 3: Pepper

Figure 4: Fake Dog

KEYWORDS

Social Agent, Human-Agent Interaction, Dog-Agent Interaction, Embodiment, Animal, Pet

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1 INTRODUCTION

In the last ten years, more and more communication agents, like Google Home or Siri, have been becoming a part of our daily life, even in the home. Communicative humanoid robots like Peppers also operate in more and more places, like airports or stores.

As those communication agents become a part of our society, it is inevitable that they interact with nonhuman members in our society. A prime example is the dog, as a beloved friend and partner to humans for over ten-thousand years [27, 33]. Dogs do not just bring both of mental [29, 38] and physical [6, 7] health to humans but also work as professional service dogs and therapy dogs. As a result of the historical long-term relationship between humans and dogs, dogs are good at interpreting social signals from humans, which include both verbal cues, like commands, and non-verbal cues, like

pointing gesture [14] or gazing. There are even some reports that pet-dogs have a tendency to prefer staying with human rather than other dogs [37]. Given this background, various experiments have been conducted to investigate which type of social agents is more suitable to dogs, humanlike or nonhuman-like [25, 32]. On the other hand, negative behaviors such as jealousy behavior[15] toward the communication agent who enters the household and communicates with dog-owners can evoke in a triad relationship. On the other hand, at the same time, dog owner's positive behavior toward agents can let dogs to accept the agent easily based on social reference[20]. Therefore, it is necessary to consider communication agents that are suitable for both owners and dogs. However, there are few researches that have investigated both dogs' behavior in front of agent-owner interaction and dog owner's preference of communication agents.

The purpose of this study is to investigate whether there are any gaps between dog-owners' positive impressions and dogs' positive behavior with the four different types of shaped agents; one dog-like speaker (Fig. 4), two humanoid robots (Fig. 2 and Fig. 3) and one smart speaker (Fig. 1). We conducted two exploratory experiments for the first step in the design of social agents for both dog-owners and dogs; the first one was for investigation of dog-owners impression toward agents and the second one is dogs' behavior while the owner was speaking to the agent and while the owner kept still and the agent was speaking to the dog.

2 BACKGROUND

Historically, agents have been used as a tool to study social behavior in studies of non-human animals. In the study of social behavior in animals, not only have agents been used as a means of simulating the results of theoretical studies, but also behavioral experiments have been conducted by placing agents with controlled behaviors in herds of animals or in close proximity to animals as a means of experimentation [13, 21, 22]. For example, Leaver et al. conducted a behavioral experiment in which medium-sized dog figurines were given motor-driven wagging tails of different lengths in order to investigate the effects of dog tail cropping on intra-species communication [19].

In recent years, beyond using agents as tools to examine the social behavior of animals, research on whether animals find sociality in agents, which are artifacts, has begun to be conducted on the sociality of the agents themselves. Studies of social cognition in companion animals relative to agents have been conducted primarily in dogs.

Dogs' reaction to animal-shaped agents. Kubiny et al. assessed various canine behaviors in 24 adult dogs and 16 pups (4–5 months old) in one-on-one encounters with four different agents under two conditions: the neutral condition (in an enclosure) and the feeding condition (during a meal). Although adult dogs and pups tended to differ in social behaviors such as "sniffing the buttocks" for living and nonliving subjects, there were differences in social behavioral tendencies between the remote-controlled car and the furred AIBO even among nonliving subjects, suggesting that the shape of the artifacts affects the response of dogs. However, it also mentioned that neither non-furred and furred AIBOs were regarded as potential rivals by adult dogs in feeding situations, as evidenced

by less growling, which indicated limited ability of AIBO as a social partner for dogs[17].

Dog's reaction to speaking agents. Dogs can understand humans' social signals, including verbal cues. Based on dogs' splendid intraspecies communication skills, researchers have worked on social agents for dogs. Lakatos et al. conducted a pointing test, in which they placed food in two bowls and allowed the dogs to choose the bowl to which the agent or experimenter pointed. The experimenter and the agent had a social condition (communicating with the dog owner in a familiarization phase and calling the dog's name during the experiment) and an asocial condition (not calling the dog's name). The experimental results showed that the social interaction of the agent did not make a significant difference in the dog's performance on the pointing test. However, the dogs spent significantly more time looking at the bowl of food pointed to by the agent in the social condition. Lakatos et al. found that the agent's behavior of "calling the dog's name" and friendly communication with a dog-owner in front of the dogs in the familiarization phase had little effect on the two-choice task for the dog, but it did affect sociality toward the dog to the extent that it affected continuous behavioral changes, such as attention time[18]

Shaw and Riley reported that a speaker can elicit desired responses from dogs if the agent speaks with appropriate attentional focus, like being placed at the height of a human's eyes and speaking in the dog-owner's pre-recorded voice, and appropriate food reward dispensing functions. There was no significant difference between the condition that the dog was alone (in the experimental room) or with both the dog owner and experimenters [35]. However, it should be taken into account that most of the dog-subjects were well-trained for competitive sports like agility, which means that their behavior may be different from ordinal dogs'.

Qin et al. reported that NAO, a kind of small humanoid robot, elicits dog's response when calling the dog's name better and was more successful in using the command "Sit down!" than a loud speaker[32].

Dogs' understanding of context. Gergely et al. reported a series of studies that showed that if using a remote controlled car as an Un-defined Moving Object (UMO), which is a stranger agent, dogs observe the agent's complex movements and go to a food dish in response, even for non-living agents, and rapidly interact socially with it by reading the context [9–11] Petro et al. reported that dogs observed the behavior of UMOs and understood the different shapes and the roles of each, and then asked for help from the appropriate UMOs to take food [26]. Abdai et al. reported that dogs that had experienced the UMO's assistance in obtaining food tended to choose the food dish that the UMO approached, even if the one that the UMO approached had less food [2]. As described above, Dogs can grasp contexts such as intentions and roles from the agent's movements in a short period of time, and sometimes they tend to be caught by agent misleading.

Differences in personality and behavior among individuals. Regarding dog-agent interaction, many studies have attempted to gain knowledge about dogs in general by using dogs of various breeds and ages for experiments, but there have also been studies that focused on the characteristics of the personality and behavior of each individual dog. It has been reported that the relationship

of the dog to the agent changes depending on the individual characteristics of the dog. Suzuki et al. conducted an experiment using Pepper, a large human-shaped robot, with two different colored aprons. When one Pepper threw the ball, the dogs that were successful in playing with the ball tended to feed at the feet of the ball-playing Pepper, and the dogs that were not successful in playing with the ball tended to feed at the feet of the Pepper that did not play with the ball. This may be a difference caused by individual dog differences, as Pepper's behavior was the same for all dogs[36]. Zamansky et al. reported that in a veterinary hospital specializing in problem behavior, locomotion was different between dogs in the deprivation syndrome group and dogs in the healthy group when they were confronted with a small dog-shaped robot [40].

3 METHODOLOGY

In the future, humanoid robots could be introduced into households as communication agents. Therefore, we conducted an experiment in which a human-robot interacted with a dog and its owner in order to investigate whether the agent could be accepted in the triad relationship among owner, dog, and agent. Two within-subjects experiments were conducted, and the order of the conditions was differentiated among the owners in Experiment 1 and among the dogs Experiment 2 by assigning them in the 24 possible variations of the order of the four conditions. Three video cameras were used to record observations during the experiment.

Ethics. Before the experiments were conducted, at least one of the owners of each dog was informed that the experiments would be recorded on video and that they could quit at any time if they thought their dog felt too scared to continue. In addition, before the experiment, each participant was asked to give written informed consent.

3.1 Subjects

3.1.1 Dog owners. Thirty-five owners participated in the experiment on the agent-owner interaction. Though eight of them participated with their dog in a pilot test for dogs, we analyzed those owners because there was no change between the pilot test and the experiment in the part of the experiment for dog-owners. However, because two of them completed questionnaires in inappropriate ways, 33 owners' questionnaire responses were evaluated in our analysis. The owners ($N=33$; 7 males, 26 females; 13 househusbands/wives, nine office workers, ten other professions, and one with no answer on professions; mean age $\pm$ SD 46.64 ± 8.15) participated in the experiment with their dogs. None of the owners owned robots, and one of the owners had smart speakers. On the other hand, there were ten owners with communication robots (e.g. Pepper, AIBO, cleaning robots like Roomba) and three owners with smart speakers, who said that they had never talked with agents on the street or shops.

3.1.2 Dogs. Thirty-one pet dogs of different breeds, genders, and ages participated in the experiment. We excluded ten dogs due to errors in the experiment or video records, as described in the Supplementary Information. Therefore, the final sample size was $N=21$ (10 males, 11 females; mean age $\pm$ SD 4.76 ± 3.60 ; mean length of living with the owner $\pm$ SD 4.57 ± 3.64), as shown in Table 2 in the Supplementary Information.

3.2 Apparatus

The experiment was conducted in a 2.7 m x 3.6 m x 2.4 m room. To prevent noise from interfering with the experiments, the ceiling and windows were soundproofed with a combination of sound insulation and sound-absorption materials. The positions of an agent and a chair in the room were fixed by marking with vinyl tape. Three video cameras were used in the experiment (Sony FDR-AX45 Handycam). The FDR-AX45 was remotely controlled using a smartphone application called PlayMemories. The experimenter set up the cameras such that the room could be watched during the experiment.

3.3 Conditions

The following four conditions were prepared for the communication agent: The shapes of the agents were as shown in Figs. 1–4. The agents' voices were set using "VOICEROID+ Tamiyasu Tomoe EX". For the communication robot, NAO and Pepper spoke with small motions such as nodding with the same name of functions set in NAOqi, an API for both NAO and Pepper developed by Aldebaran Robotics.

- **Google Home** is a smart speaker which has a primitive body shaped like a column, as shown in Fig. 1, with a diameter of 9.64 cm, height 14.3 cm, and weight of approximately 0.5 kg.
- **NAO** is a small humanoid robot designed and developed by Aldebaran Robotics, as shown in Fig. 2, with a height of 58 cm, weight of approximately 5.4 kg, and 25 degrees of freedom.
- **Pepper** is a large humanoid robot designed and developed by Softbank Robotics, as shown in Fig. 3, with a height of 121 cm, weight of approximately 29 kg, and 20 degrees of freedom.
- **Fake Dog** is a communication agent with canine appearance, shown in Fig. 4. Harris et al. [15, 30] conducted a triad relationship experiment between an owner, a dog, and a third party, and observed differences in the dogs' responses depending on the type of third party. It was found that the canine response was greater when owners and other humans paid attention to the Fake Dog, compared to other simple-shaped puppets and books.

3.4 Procedure

The experiment was divided into two types of experiments: a dyad relationship experiment in which the owner's impressions of the agent were evaluated in the owner-agent space, and a triad relationship experiment in which the behavior of the dog was evaluated in the owner-dog-agent space. The owners and their dogs waited in the waiting room, where the owners signed the consent form and answered a questionnaire including the names and ages of the owners and the dogs.

3.4.1 Experiment 1: Dog owners' perception of the communication agent. The test dog was waiting in the waiting room with the dog sitter. We contacted the owners in advance to ask them to bring their dogs' favorite toys, treats, and pet sheets for the dogs to have during the time in the waiting room. At the same time, we conducted an exploratory experiment using a within-subject design as follows:

- (1) We explained the experiment in dyad relationship space to the owners as an "exercise of the owner's behavior" to evaluate the behavior of the dogs when the owner is interacting with the agent. As an example of the behavior, we asked the owners to "pet the agent while talking to the agent, using the same words and tone of voice as you would normally use to praise your dog or another dog in front of your dog".
- (2) The owner entered the experiment room and sat down on the chair in front of an agent.
- (3) The agent greeted the owner and asked for a pat on the head.
- (4) After 10 seconds, the agent asked the owner to go out of the room.
- (5) The owner provided their ratings for the agent based on GODSPEED (described in detail later in this section).
- (6) Steps 2-5 were repeated for four agents considering counter-balancing of the order of the agents.

3.4.2 Experiment 2: Dogs' behaviors in the space with the owner and communication agent. This experiment was conducted as follows:

- (1) To acclimate the dog to the laboratory, the owner and the dog entered the room together and searched the room for 2 minutes. In many canine laboratory experiments, the acclimation time to the laboratory ranges from 30 seconds to a few minutes, so in our study, we chose 2 minutes [3, 10]. The experimenter waited outside the door of the laboratory and, after 2 minutes, the owner and the test dog were escorted into the waiting room.
- (2) The owner entered the experiment room again and sat down on the chair in front of the agent.
- (3) Just after the owner began the interaction with the agent, the experimenter let the dog enter the room.
- (4) After the agent's instruction, the owner started patting the agent's head with a positive voice saying phrases such as "Good boy!" without reaction from the dog for 1 min (**agent-owner phase**). During the 1 min, the agent emitted voice expressing its happy emotion like "Yippee!" every 10 seconds.
- (5) After the agent's instruction, the owner kept still and silent without reaction to their dog for 1 min. Every 10 seconds, the agent spoke to the dog, calling the dog's name (that the owner uses in positive situations at home) for three of the times, and giving agents' name for three of the times in a random order (**agent-dog phase**).
- (6) As instructed by the agent, the owner and dog left from the room.
- (7) Steps 2-6 were repeated for four agents with considering counter-balanced of the order of the agents.

3.5 Measurement

3.5.1 Questionnaire for dog owners. To evaluate the owners' impressions of the agent in **Experiment 1**, we used a psychometric measure called GODSPEED [4], which contains five scales considered in the research of interaction between people and social agents: *anthropomorphism* (ascribed as human-likeness), *animacy* (ascribed as perception of being alive), *likability*, *perceived intelligence*, and *perceived safety*. GODSPEED has been widely verified, and the words and their order of appearance are fixed and translated

Table 1: Behavioral categories recorded during both owner-agent and agent-dog phases

	Behavioral category
B1	Getting between the owner and the agent
B2	Touching / Pushing the owner
B3	Touching / Pushing the agent
B4	Whining
B5	Stress signals[31]
B6	Barking
B7	Staring at the agent from behind of the owner
B8	Staying in front of the door
B9	Touching / Pushing the head of the agent
B10	Touching / Pushing the paw of the agent
B11	Touching / Pushing the front part of the agent
B12	Touching / Pushing the back part of the agent

into 15 languages. Hence, GODSPEED is often used in research on human-agent interaction [39].

3.5.2 Dogs' behavioral analysis. After synchronizing the video recording by three video cameras using the function of Adobe Premier, two coders analyzed the dogs' behavior in Experiment 2, shown in Table 1. The definition of *Stress signals* in B5 are stress-related behaviors, such as paw raising, nose-lip licking, shaking, yawning, and scratching [31]. We coded B1 and B2 as a category for jealousy behavior [15]. B3 and B7-12 were coded for investigating if dogs could approach to the agent or not and if dogs approached with recognizing some part of body of agents (a face and hands). We defined that a dog touched or pushed things if the dog's muzzle reached to the things in 10 cm in B1-2, B9-B12. The coders counted the categorized behavior in the three conditions (NAO, Pepper, and Fake Dog) in B9 and B10, otherwise in all four conditions, because Google Home does not have a head. The coders were professional dog trainers. The first coder was a fulltime dog-trainer who trained dogs of both of big- and small-size dog groups. The second coder was a part-time dog-trainer who trained mainly small-size dogs and had another profession too. Behavior analysis was divided into **agent-owner phase** and **agent-dog phase**. The **owner-agent phase** was between the dog entering the room and the owner standing still at the agent's direction, and the **agent-dog phase** was after the owner is standing still, while the owner started moving with instructions from the agent. The coders scored "1" if the dog did a specific behavior (at least once) during each phase, and otherwise scored "0".

4 RESULTS

We conducted statistical analysis on quantitative data using IBM SPSS 22. The p -values less than 0.05 were considered statistically significant. The tables showing the results of calculating the p -values and the effect size, r , are in the Supplementary Information.

4.1 Dog-owners' impressions of the agents

The histogram of Fig. 5 summarizes the result of rating by the human-subjects in the owners' impressions of the agents among the four conditions between "1" (minimum) and "5" (maximum). We analyzed the significant differences in the owners' impressions

Figure 5: Comparisons of histograms of each agent's rating (Lowest=1, Highest=5) by participants based on GODSPEED.

toward the agents among the four conditions using the Friedman test. Calculation of p -values, showed significant differences in the mean scores among the mean four conditions in all of the factors in GODSPEED, as shown in Table 6 in the Supplementary Information. We also calculated the p -values and the effect size r of each pair of conditions in anthropomorphism, animacy, likability, perceived intelligence, and safety using the Wilcoxon signed-rank test corrected with the Bonferroni correction, as shown in Table 7 in the Supplementary Information. There were significant differences as follow:

- **Anthropomorphism:** NAO, Pepper > Google Home, Fake Dog
- **Animacy:** NAO, Pepper > Google Home > Fake Dog
- **Likability:** NAO, Pepper > Google Home > Fake Dog
- **Perceived intelligence:** NAO, Pepper > Google Home > Fake Dog
- **Perceived safety:** Pepper > Fake Dog

4.2 Checking Dog's Profile

Before conducting the experiment 1 and 2, we asked the dog owners about the character (dominant/subordinate and jealousy level) of their dogs because we thought that those characters can be related to boldness or aggressiveness in front of agents or behavior to attract owners' attention. We took this step for checking that the subject group does not have special tendency to the extreme extent.

Evaluating the dog-subjects' dominant rank. Using the questionnaire [3, 28] used by Abdai et al. in their behavioral experiment of dogs in the triad relationship among owner, dog, and third party (artifacts such as a remote-controlled car or other dogs), we also investigated whether the test dogs were likely to be higher or lower in the domestic pecking order. The questionnaire items are as follow:

- Q1. When a stranger comes to the house, which dog starts to bark first (or if they start to bark together, which dog barks more or longer)?
- Q2. Which dog licks the other dog's mouth more often?
- Q3. If the dogs get food at the same time and at the same spot, which dog starts to eat first or eats the other dog's food?
- Q4. If the dogs start to fight, which dog usually wins?

The evaluation of whether the dog was high or low in the domestic pecking order was based on the results of Q4. When the name of the test dog was not mentioned in Q4, and it was mentioned in at least two of the items in Q1–Q3, the dog was evaluated as *dominant*, and otherwise as *subordinate*. Results indicated (*the details are shown in the Supplementary Information*), seven dominant individuals, six subordinate individuals, six unidentified individuals, one individual which we could not decide as "subordinate or unknown," and one individual which we could not decide as "dominant or unknown". There were no tendencies to biases in the dog-subject' dominance rank in our experiment.

Evaluating the dog-subjects' jealousy level. Because jealousy could affect a dog's behavior in the presence of an agent interacting with the dog's owner, it was important that the subject group did not have strong bias of jealousy behavior. Thus, we utilized the questionnaire applied to 631 dogs by Abdai et al. [3] to check our dog-subjects jealousy level. The questionnaire items are as follow:

- Q1. How jealous do you think your dog is compared to the average dog? (scale from 1 to 10) (mean ($\pm$ SD) 5.68($\pm$ 2.67) in the previous survey[3])
- Q2. Who does the dog usually gets jealous of?
- Q3. Where does your dog get jealous? (at home, at unfamiliar places; on a scale from 1 to 5) (mean ($\pm$ SD) 3.19 ($\pm$ 1.43), 2.36($\pm$ 1.33) in the previous survey[3])

Owners that filled in the questionnaire in the present study gave a mean ($\pm$ SD) 5.33 ($\pm$ 2.55) jealousy score to their dogs; a mean ($\pm$ SD) 3.19 ($\pm$ 1.30) score at home, and 2.70 ($\pm$ 1.23), score at unfamiliar places, although one owner did not answer the score. There were no tendencies to biases in the dog-subject' jealousy level in our experiment (the details are shown in supplementary information).

4.3 Dog Behavior in front of agents with the owner

Based on the video recorded from three angles, the two professional dog-trainers counted 21 dog's behaviors, listed in Table 1. As the result of their coding, the concordance rates between the two coders' decisions were above 90% in three categories (B4(91.67%), B6(96.43%) and B8(91.67%)) of the dogs' behavior in the **agent-owner phase** and four categories (B4(97.62%), B6(91.67%), B9(93.13%) and B12(90.48%)) of the dogs' behavior in the **agent-dog phase**, as indicated in Table 11 in the Supplementary information. For statistical analysis, we adopted the result of coding by the first coder in the categorized behavior whose accordance rate between the two coders was beyond 90% for the reasons described in Section 3.5.2. The accordance rate was calculated as the percentage of the same result of coding by the first and second coder among all subjects and the all conditions in each category in each phase.

Figure 6: Comparisons of the proportions of dogs exhibiting each type of behavior in each of the four experimental conditions.

Fig.6 summarizes the analysis of the proportion of dogs exhibiting the categorized behavior. We analyzed the significant differences on the proportion of dogs exhibiting categorized behaviors in front of the agents in the three conditions (NAO, Pepper, and Fake Dog) in B10, and otherwise among the four condition, as mentioned in Section 3.5.2, using Cochran's Q test. We excluded B9 for statistical analysis because the height of Pepper is too high compared to other agents though coding B9 is meaningful in NAO and FakeDog. As the result of calculation of the p -value as shown in Table 8 in Supplementary information, there were significant differences in B4 in the **agent-owner phase** B12 in the **agent-dog phase**. We also calculated the p -values of each pair of two conditions for those behaviors using the McNemar test with Bonferroni correction. As the result of the McNemar test, though there was significant difference on B4 in the **agent-owner phase** and B1 in the **agent-dog phase** tested with Cochran's Q test, there were no significant differences between any pair of the conditions on B6 in the **agent-owner phase**. On the other hand, there was significant difference B12 in the **agent-dog phase**, as Fig. 6 shows.

Subsequently, we conducted statistical analysis on the small dog group and the large/medium dog group in the same flow using Cochran's Q test and the McNemar test corrected with the Bonferroni correction. We separate the dog-subjects based on the size because in an experiment using a stuffed dog with robotics tail, Leaver et al. conducted the statistical analysis on small and medium/large groups separately, and from other conditions there were significant differences only in the large group approaching to the stuffed dog with the waving long robotics tail, which implies that size of the dog-subject can be a factor affecting dogs' behavior toward an agent[19].

Figure 7: Comparisons of the proportions of dogs exhibiting each type of behavior in each of the four experimental conditions in agent-dog phase between sizes of dogs.

Table 9 and Table 10 in the Supplementary information show the result of calculation of p -values in smaller dogs and larger dogs, respectively, using Cochran's Q test and the McNemar test with the Bonferroni correction. In both groups, there was no significant differences on B4, B6 and B8 in the **agent-owner phase**, as shown in Fig. 12 in the Supplementary information. There was a significant difference ($p=0.029$) among the four condition in B14 in medium/large dog group in **agent-dog phase** with Cochran's Q test. However, there was no significant difference in any pairs of the conditions as the result of the McNemar test as shown in Fig. 7.

4.4 Case Based Analysis of Dog's Behavior

Most owners sat alone in a chair in the center of the room following our instruction before the experiment. However, in the Fake Dog condition, there were a few owners who did not proceed smoothly to the chair, for example by stopping at the entrance of the experimental room.

In quantitative analysis, the proportion of the dogs which touched the rear (B12) of the Fake Dog (Fig.9) was significantly higher in **agent-dog phase**. In the **agent-owner phase**, despite their small body size, small dogs touched the head of the fake dog with their muzzle by placing their dogs' paws on the owner's lap or the pedestal, and standing, as shown in Fig. 10. There were also other ways observed for dogs to contact the Fake Dog such as placing a muzzle around the Fake Dog's neck for a while or scratching the rear of the fake dog with the dog's paw (Fig.10). In some cases, dogs sniffed the hand of the humanoid robot, as shown in Fig.11, which implies a protrusion like a hand of humanoid robot is easily perceived by dogs. Many dogs gazed the owner and an agent as if

Figure 8: Examples of a dog sniffing the rear of the Fake Dog.

Figure 9: Small dogs stretching its the body to touch the head of Fake Dog.

Figure 10: The dog in the left picture scratching the back of Fake Dog, and the dog in the right picture keeping touching the neck of Fake Dog with his muzzle.

Figure 11: Examples of dogs touching the hand of agents.

social reference [20] as shown in Fig. 13 in Supplementary Information. Some small-size dogs sniffed the head of NAO, as shown in Fig. 14 in Supplementary Information, though the dogs could not touch the head of Pepper. There is a dog which oriented at an agent almost in the Fake Dog condition (Fig. 15 in Supplementary Information).

5 DISCUSSION

The most remarkable points in our exploratory experiment are the following:

- The dog-owners evaluated Fake Dog, a speaker with dog-like appearance, with the lowest scores in all of perceptual factors of GODSPEED, namely, anthropomorphism, animacy, likability, and perceived intelligence and safety. Surprisingly, Fake Dog scored lower than Google Home not only in perceived intelligence but also in animacy and likability.
- the dog-owners evaluated humanoid robots with highest scores in all perceptual factors of GODSPEED.
- Dogs expressed social behavior, like sniffing the rear of the agent in the Fake Dog condition in the **agent–dog phase**.

The dog-owners seemed to feel confused in the presence of Fake Dog. Some of the owners froze upon seeing the Fake Dog when entering the experimental room, as described in Section 4. Additionally, Fake Dog cannot move like a real dog despite of its realistic appearance. This mismatch between the appearance and ability can disappoint the owners. Matching agent's appearance and behavior is reported as a key for human–agent interaction[12]. Especially, in dog-like robots, it is reported that people scored AIBO lower in the interaction after an experimenter introduced AIBO as a "living thing" using the words "he" and "him" rather than framing it as a "robot" using the words "AIBO" and "its" [34]. In a previous study, the authors made an assumption based on the idea of "uncanny valley"[24] and advocate the acceptability of the new AIBO, a deformed dog-like robot [34]. Here, we do not discuss whether the owner's evaluation of this Fake Dog is due to perception of the uncanny valley. However, Fake Dog's "too realistic appearance" can be a factor causing some kind of discomfort to the dog-owners.

In the neutral situation, where is not a feeding situation, the appearance of the Fake Dog can evoke social behavior like sniffing, though in previous study the other dog-like agent, furry AIBO, evoked limited social behavior in a neutral situation compared to a puppy and a car[17]. Moreover, realistic plastic dogs and stuffed dogs have been used for investigating dog's social behavior to as a target of the sociality because it is difficult to control a living dog as a test-partner [15, 30]. In those studies, though there was an advantage in ease of controlling, the authors mentioned the limitation of fake dogs as test-partners which evoke social behavior. On the other hand, there are several reports on primitive agents like remote control cars eliciting (evoking) dog's perception of interactivity or sociality toward the agent by acting in helpful and complex ways. Some researchers propose the importance of the agent's behavior to evoke dogs' perception of animacy or interactivity toward the agent [1]. In addition, the results in our exploratory experiment casted a new possibility of effective utilizing way of a physical agent with realistic embodiment evoking dog's perception as a "hook" in the first contact to some extent.

For future works, it is also worth noting that regarding B9 in the **agent–owner phase**, of course, small dogs cannot touch Pepper's head, though none of the medium or large dogs came in contact with Pepper's head. Meanwhile, a third of the medium and large dogs had contact with the NAO's head. In addition, 30% of medium and large dogs contacted Pepper's head in the **agent–dog phase**. One of the most characteristic features of the head is the eyes. The

presence of the eyes was incorporated as one of the factors causing the difference between the social condition and the mechanical condition agent in the evaluation of dog behavior for undefined moving objects using a remote controller by Gergerly and colleagues (However, Gergerly et al.'s experiment included more than just the eye, so the effect of the eye alone was not clear) [11]. As a fact, dogs understand the humans' field of vision [16] and attentional state [5], then react sensitively as well as humans' body orientation [8]. Even in medium to large dogs, head contact may require a decrease in alertness over time. However, we could not conclude this in the present experiment, so this will be a subject for future work to verify.

Other validation issues in the future work include the triad relationship due to the presence of the owner. In the present experiment, because it was a space of the triad relationship in which the owner was present in the laboratory, it is thought that there was an influence of social reference [20] in observing the owner's reaction to the agent. However, since we did not conduct a counter-balanced experiment between the **agent-owner phase** and the **agent-dog phase**, it is not possible to determine what difference agent-owner interaction made in dog behavior toward the agent and what difference the agent's embodiment made in that case.

Moreover, though we evaluated behavior of the dogs as behavioral analysis, it can be also important as a future work to investigate how the dog-owners interact with agent under an instruction that the owners should behave petting the agent with the same tone and vocabulary when they usually praise their dog. Investigating the dog-owners behavior can bring us a key to develop social agent with dog-owners because the way of interaction was varied among owners (the owners keep the same way among the four agents as possible).

5.1 Generated Hypotheses

Overall, hypotheses from this exploratory experiment to further research include the following:

- Hypothesis 1: Dog owners have a negative impression toward a dog-like communicative agent speaking human language.
- Hypothesis 2: Dog owners have relatively negative impression ratings of a realistic-looking dog-like communication agent compared to deformed dog-like communication agents.
- Hypothesis 3: Differences in dog size affect the dog's proximity to the agent.
- Hypothesis 4: Agent shapes (primitive, dog-like, humanoid) in the same size affect the dog's proximity to the agent.

6 LIMITATION

First, the number of medium and large dogs included in the analysis is small. The analysis was divided by canine size, but the results for medium and large dogs were insufficient for statistical analysis. One reason for this is the difficulty of instructing the owner. Although many medium and large dogs participated in the experiment, their owners sometimes did not behave as instructed. Many of the owners who participated in this experiment were office workers or househusbands/wives, so the experiment was difficult to control. In the **owner-agent phase**, the owners were instructed to behave

towards the agents in such a way that there was no difference between each agent condition, and to treat the agents with the vocabulary and tone of voice that they normally use when praising their dogs. However, it is difficult for the average owner to be aware of and adhere to these instructions. Related to our mis-instruction for owners, leash on dogs during our experiment was also problem as shown in Fig.8 and Fig.10. Actually, the dogs with leash moved in the experiment room without their owner's grab. However, even without owner's grab, leash can affect dog's behavior like gazing[23].

Secondly, there is an inadequate setting of standards for behavioral evaluation. The only one behavioral evaluation that had high agreement by the coders and a significant difference between the agents was "touching the agent's rear" (B14). We should have set other categories of dog's behavior to be coded. As an evaluation of dog's perception of sociality, interactivity, and positivity toward the agents, a pointing test or the choice of one of the two agents is also used. However, in this experiment, the pointing test could not be performed because there were agents who could not move, but we would like to examine the evaluation method of making the dogs choose an agent in the future.

7 CONCLUSION

Dogs are mankind's oldest friends since ancient times. Recently, social agents have been becoming part of family life, and those social agents should build good human-agent and dog-agent relationships at home. To investigate how social agents are perceived by dog owners and dogs with existing communication agents such as smart speakers, we conducted two experiments, on owner's impression toward agents in agent-owner interaction and dog's behavior in front of the agent during and after agent-owner interaction, and statistically analyzed the result of 33 dog-owners and 21 dogs. The results of the GODSPEED analysis showed that the dog-like smart speaker was significantly worse than the humanoid robot, NAO, and Pepper in Anthropomorphism, Animacy, Likability, and Perceived Intelligence. In addition, the dog-like smart speaker was rated significantly lower than Google Home in Animacy, Likability, and Perceived Intelligence and lower than Pepper in Perceived Safety. On the other hand, in the dog behavioral analysis, the percentage of individuals who engaged in social behaviors (e.g., sniffing the rear) in response to the dog-like smart speaker was significantly higher than that for the other agents. Although an exploratory experiment in terms of subject limitations and determination of behavioral indicators, this study is a first step in challenging the gap between owners and canines for the same physical agents.

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