Man's New Best Friend? Strengthening Human-Robot Dog Bonding by Enhancing the Doglikeness of Sony's Aibo

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***Abstract*— Commercial robotic dogs, such as Sony's Aibo, have recently been reimagined. Our goal with this research was to examine factors that influence human-robot dog bonding. We created a 2x2 between-subjects experiment, by framing the Aibo as a puppy or robot, and by adding fur to the Aibo or not. We hypothesized that bonding would be stronger when the robotic dog was framed to participants as a puppy rather than a robot, and it would be stronger when the robotic dog was dressed in a fur suit. Results showed that participants were less positive toward Aibo when framed as a puppy compared to when Aibo was framed as a robot. Adding fur had a positive effect: Aibo was considered less scary compared to having no fur. In addition, behavioral interaction results showed that asking the Aibo to "come here" was the most popular command with respect to the number of completed actions, failures, and social behavior, and the time spent. Our approach could inform design in a way that integrates dogs into the work force to help people relieve boredom, stress, and help them carry out their jobs more effectively and cost efficiently.**

Keywords—Trust, zoomorphism, robot dogs

I. Introduction

A. Aibo: Sucessfully Creating Bonds with Social Robots

Bonding between humans and social robots can be beneficial in many contexts, including battling isolation in older adult care [1,2], alleviating stress and boredom in employment sectors [3,4], and facilitating behavioral therapies for special needs populations [5,6]. This issue is especially relevant given the current mass social distancing measures employed due to the global COVID-19 pandemic. For example, applications for dog rescues have increased [7] presumably to alleviate increasing rates of loneliness [8] caused by many people living and working from home.

However, creating lasting interactions between humans and social robots has been a particularly challenging goal for the human-robot interaction community. Recent years have seen the closing of several high-profile social robotics companies which design and sell consumer-grade social robots specifically intended to serve as long-term companions, partners, and teammates for humans (e.g., Anki, Jibo, Mayfield). One social robot, however, that has an iconic status in forming and maintaining interactions with people is Sony's dog-like robot, Aibo. To illustrate, Aibo was first introduced to commercial markets in 1999 and sold over 150,000 units. Because Aibo was not considered a commercial success, Sony halted production of the robotic dog in 2006 and stopped supporting software updates and maintenance in 2014. As a result, users saw their beloved robotic companions slowly become nonfunctional and irreparable. News quickly spread of elaborate funerals and mortuary rights for Aibo [9]. This report estimated that approximately 700 Aibos have received Buddhist funeral ceremonies and that private companies have emerged to, "Help people cope with the breakdown of robots they have become attached to (p.2)."

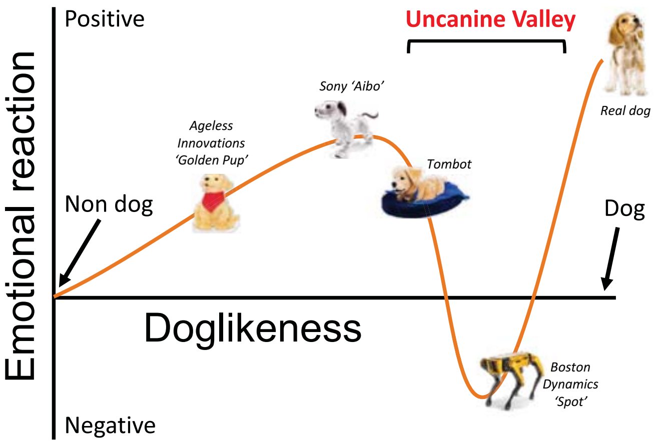

Fig. 1. *Representation of the "uncanine" valley, a hypothesized adaptation of the uncanny valley [10].*

B. Previous Research

Shortly after the initial wave of success of Aibo, researchers began investigating social behaviors toward and attachment to the robotic dog. For instance, previous research found that they could elicit caretaking behaviors in adults if the Aibo was considered a "baby" and displayed a "needy" attachment profile [11]. Similarly, others found that if the robot over time exhibited developmental changes, then participants perceived the robot as more life-like and engaged in more social responses toward the Aibo [12]. Studies with children have also shown that a surprising majority of children conceptualized and interacted with Aibo as if it were a live dog [13]. Further, research has shown that successfully interacting with social robots reinforces people to form positive attitudes toward the robots in the early phase of interactions. However, in recent

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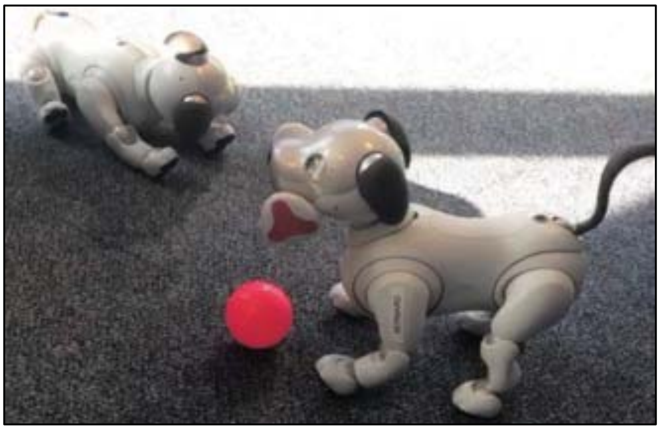

Fig. 2. *Kipling and Bernard, Aibo's playing with their toys.*

study, initial interaction successes with Aibo were fewer than with the small social robot, Cozmo (by Anki) [14]. These findings may highlight a trade-off between the benefit of early success in completing simple tasks with a social robot, and the long-term benefits of "training" of social robot like Aibo which could sustain interactions over time [14].

Finally, the robot's form may also be an important moderator in whether people engage in long-term interactions with social robots. For example, news reports have indicated the emergence of uncanny robot dogs [15,16], which may indicate the existence of an "Uncanine valley" (see Figure 1). Indeed, recent work has demonstrated such a u-shaped valley effect for zoomorphic robots [17]. Moreover, several researchers have shown that increasing a robot's human-like or zoomorphic appearance can greatly influence perceptions that may aid in bonding [18,19]. Such effects include positive perceptions such as a robot's sociability [20], but also negative perceptions like creepiness and eeriness [21].

C. Present study

In 2018, Sony re-imagined Aibo with the wide commercial release of the fourth generation Aibo robotic dog—the ERS 1000. The purpose of the present study, therefore, was to investigate factors that could influence interaction behaviors with the new Aibo, especially behaviors which could facilitate bonding and long-term social interactions. In addition, we sought to examine the influence of different form factors of Aibo on participant interactions and perceptions of Aibo. In following with previous studies which showed that framing Aibo as a developmental agent (e.g., learning over, time, needing to be cared for), can facilitate more engagement with the robot we offered the first hypothesis:

Hypothesis 1 (H1): Participants will respond more positively to an Aibo that is framed as a puppy (i.e., in need of development) rather than simply a robot.

Because research has also shown that as robot appearance approximates the intended agent it mimics (e.g., human-like), it may result in more positive assessments of the robot, we also proposed the second hypothesis:

Hypothesis 2 (H2): Adding fur to an Aibo to increase its dog-like form, will result in more positive assessments of the Aibo than an Aibo without fur.

II. Methods

A. Participants

Disruptions to in-person data collection due to the spread of COVID-19 resulted in only 33 participants (Age = 18-26; Females = 12) completing the study. All participants were recruited from the U.S. Air Force Academy and volunteered to participate in this study in exchange for course credit. All participants claimed that they liked dogs. Except for three individuals, all participants had previously owned a pet.

B. Apparatus and Materials

Two ERS-1000 Sony Aibo dogs (Software version 2.5.1) were used for participant interaction in this study. The ERS-1000 has several cameras, sensors, and microphones that allow it to sense its environment (see Figure 2). Aibo has two expressive OLED eyes that are used to convey expressions that the robot is tired, angry, or excited. Its ears, head, and tail can move to add further expressiveness and doglike behavior. For the purposes of our experiment, we made one adaptation to Aibo by designing a fitted fur suit. The suit was made from white textile faux fur that gave a realistic feel when touched and shed like a real dog. The fur was designed as a bodysuit on the dog and covered its back, shoulders, and hips. We attached the fur to the dog using Velcro. Along with the Aibos, we used a Lenovo ThinkPad laptop to video record the interactions that the participants had with the Aibos. Additionally, we used any open space, without any other people present, that was available for the participants to interact with the dog. All questionnaires were administered to participants using Google Forms.

C. Experiemental Design

The experiment used a 2 x 2 between-subjects design with two factors: Framing of the Aibo (Puppy vs. Robot) and Skin: (Fur vs. No Fur). Participants were randomly assigned to one of the four experimental conditions.

We framed the Aibo as either a puppy or a robot when introducing Aibo to the participants. Two different scripts were developed for this purpose. In the Puppy condition, Aibo was introduced by indicating that the dog was a puppy who was in training. We also used its name (Kipling or Bernard) and gendered pronouns like "he" and "him." In the Robot condition, Aibo was described as a robot, and was called, "Aibo" and spoken about using non-gendered pronouns like "it." The Skin conditions consisted of Aibo either having Fur or No Fur. In the Fur condition, Aibo was outfitted with a fur suit (see Figure 3). In the No Fur condition, the Aibo was presented to participants in its factory condition, without the fur suit.

D. Task Paradigm

After the Aibo was introduced to the participants, they were given a list of commands that they could try with the Aibo. If Aibo understood a given command, Aibo would respond by engaging in a behavior associated with the command.

Participants were instructed to attempt various commands with Aibo. The commands and associated behaviors are shown in Table 1.

E. Measures

For this study, we used questionnaire assessments after a brief introduction of the robot dog, and again after interacting with Aibo to assess whether participants changed their opinions of Aibo in a pre-post design. We asked participants to fill out a customized scale where participants rated their perceptions of Aibo across 10 characteristics: creepiness, likability, scariness, trustworthiness, uncanniness, doglikeness, consciousness, lifelikeness, intelligence, and friendliness. To establish clarity across participant ratings, we provided participants with definitions of each of the characteristics. Definitions were derived from definitions found in the Oxford English and Merriam Webster's Dictionaries, and Dictionary.com. Participants rated the Aibo both before and after interaction on each characteristic using Likert-type scales which ranged from 0 (not at all) to 10 (extremely).

TABLE 1. COMMANDS AND ASSOCIATED BEHAVIORS FOR AIBO.

Command	**Behavior**
"Very lovely Aibo"	Dances and barks as it plays very lovely song
"Sit Down"	Sits down in doglike posture and pants
"Take a Picture"	Counts down and snaps picture with camera
"Sing a Song"	Strikes a sitting pose and sings melodic tune
"Come Here"	Turns to speaker and walks to him or her
"Happy Birthday"	Dances and barks as it plays happy birthday
"Let's Pose"	Rolls over on belly and moves feet
"If You're Happy…"	Dances and barks to the famous song

Two additional items were included on this questionnaire as well; whether participants felt a connection with the dog, and whether they thought the dog was warm and caring, rated from 1 (*strongly disagree*) to 5 (*strongly agree*). Lastly, we recorded participants' interaction with Aibo and coded each of the videos on several behavioral measures. Behavioral measures included Aibo task completion (number of times that Aibo successfully followed a command), Aibo task failures (number of times that Aibo failed to follow a command), task duration (the total amount of time spent attempting a command) and participant social behaviors (total number of smiles, pets, laughs, praises and name uses).

F. Procedure

Participants began the experiment by reading the informed consent form. They were then randomly assigned into one of the four experimental conditions and guided to the experimental room where participants were either introduced to an Aibo with

Fig. 3. *Bernard, an Aibo outfitted with a fur suit.*

a fur suit or without the fur suit. We then read the appropriate script either framing Aibo as a puppy or the script framing Aibo as a robot. After a brief introduction to Aibo, the participants then filled out the pre-interaction questionnaire, rating Aibo on the characteristics described above. The participants were then instructed to attempt each of the eight commands with Aibo. A laptop was used to video recorded the participants interacting with Aibo. The experimenter left the room to allow participants to freely interact and attempt commands with Aibo. After 10 minutes, we asked the participants to fill out the post-interaction questionnaire, rating Aibo on the 12 characteristics again. The participants were then thanked for their participation and provided with extra credit in return for their participation. The entire experiment took approximately 20 minutes to complete.

III. RESULTS

First, we investigated whether the participants evaluated Aibo differently before and after interacting with it, and if this potential difference varied across measures of their subjective evaluations of Aibo (i.e., perceptions of creepiness, likeability, scariness). We performed a 4-way ANOVA where Skin (2: No fur vs. Fur) and Framing (2: Robot vs. Puppy) were treated as between-subjects variables and Experience (2: Pre- vs. Post-interaction) and Measure (12 different subjective measures) were treated as within-subjects variables. There was a significant main effect of Experience (Pre- vs Post-), $F(1, 29) = 9.03$, $p = .005$; and a significant main effect of Measure, $F(11, 319) = 30.65$, $p < .001$. These results indicate that the pre-interaction ($M = 4.51$, $SD = 2.69$) and post-interaction ($M = 4.93$, $SD = 2.84$) ratings were different and the ratings were different across measures ($_{\text{Range}}M = 1.45{\sim}7.09$, $_{\text{Range}}SD = 1.08{\sim}2.97$). There also was a significant interaction effect of Experience and Measure, $F(11, 319) = 5.36, p < .001$, indicating that the degree of the difference between the pre- and post-interaction ratings significantly varied across different subjective measures (e.g., perceptions of the creepiness, likeability, scariness). No significant effects involving either Framing or Skin were found. As there was evidence suggesting that the participants' ratings of Aibo were different between the pre- and the post-interaction, we next examined the effects of

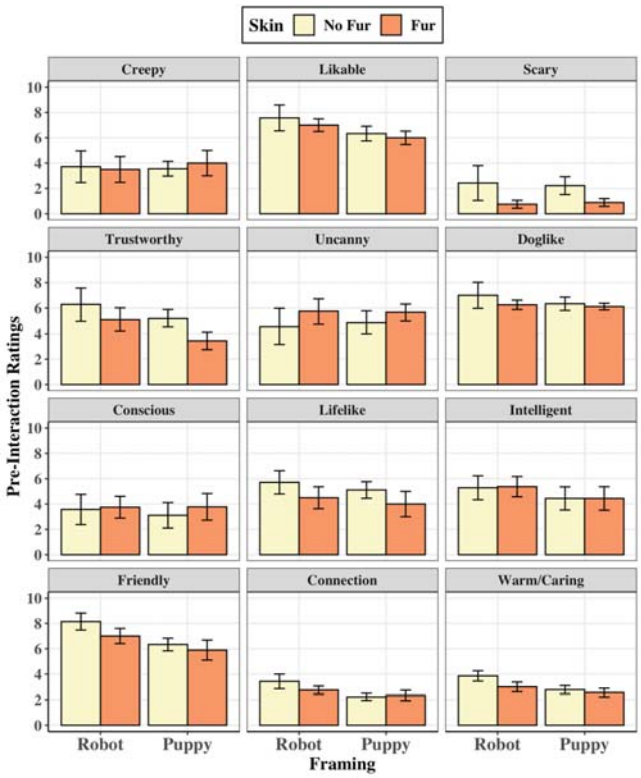

Fig. 4. *Pre-interaction ratings for all measures*

Framing and Skin separately within the pre- and the post-interaction ratings. Specifically, we conducted two 2 (Framing: Robot vs. Puppy) by 2 (Skin: No fur vs. Fur) between-subjects multivariate analysis of variances (MANOVAs) on the pre and the post-interaction data sets, respectively. We did not find any significant effect of Framing and Skin in the multivariate analyses, but the univariate analysis of variances (ANOVA) revealed significant effects of Framing and Skin on some of the measures.

A. Pre-interaction Ratings

Across the scariness ratings, we found a significant effect of Skin, $F(1, 29) = 4.15$, $p = .05$ (see Figure 4). Participants judged Aibo wearing a fur suit ($M = 0.82$, $SD = 0.88$) as less scary than Aibo not wearing a fur suit ($M = 2.31$, $SD = 2.77$). Next, we found significant main effects of Framing, in the pre-interaction ratings of friendliness, $F(1, 29) = 4.88$, $p = .04$; connection, $F(1, 29) = 4.10$, $p = .05$; and warm/caring, $F(1, 29) = 4.36$, $p = .05$. However, the direction of these main effects of Framing deviated from Hypothesis 1. First, the participants judged Aibo as friendlier when it was framed as a robot ($M = 7.53$, $SD = 1.77$) rather than a puppy ($M = 6.11$, $SD = 1.94$). Second, compared to when Aibo was framed as a puppy ($M = 2.28$, $SD = 1.02$), the participants felt that they had a stronger connection with Aibo when it was framed as a robot ($M = 3.07$, $SD = 1.22$). Finally, the participants perceived Aibo as warmer and more caring when it was framed as a robot ($M = 3.40$, $SD = 1.12$) than when it was framed as a puppy ($M = 2.67$, $SD = 0.97$). These results suggest that perhaps framing Aibo, a robotic dog, as a real dog by calling it a puppy and giving it a name might have backfired, making the contrast between a real dog and a robot dog apparent in the eyes of the participants.

B. Post-interaction Ratings

To examine if a brief interaction with Aibo led to any changes in the participants' evaluation of the robot, we inspected the effects of Framing and Skin for each dependent measure. Again, there was a significant main effect of Skin for the scariness ratings, $F(1, 29) = 4.83$, $p = .04$ (see Figure 5). When Aibo was wearing a fur suit ($M = 0.59$, $SD = 0.94$), the participants perceived the robot as less scary than when it was not wearing a fur suit ($M = 2.19$, $SD = 2.86$). No other effects were statistically significant. For example, there was no longer a significant difference between the puppy and the robot framing condition in the ratings of friendliness, connection, and warm/caring. These changes may suggest that, as the participants interacted with Aibo, the difference between framing Aibo as a puppy or a robot decreased. To verify the significance of this potential positive effect of interaction, we additionally performed 2 (Skin: No fur vs. Fur) by 2 (Framing: Robot vs. Puppy) by 2 (Experience: Pre- vs. Post-interaction) ANOVAs, one for each of the 12 measures. We did not find any significant interaction effects, however, indicating that the differences in the pre-and the post interaction ratings for some of the dependent measures were not strong enough to reach a statistical significance.

C. Interaction Behavior

For 28 of the participants, video interaction data was recorded and available for analysis. We coded and analyzed the observed behaviors while participants interacted with Aibo.

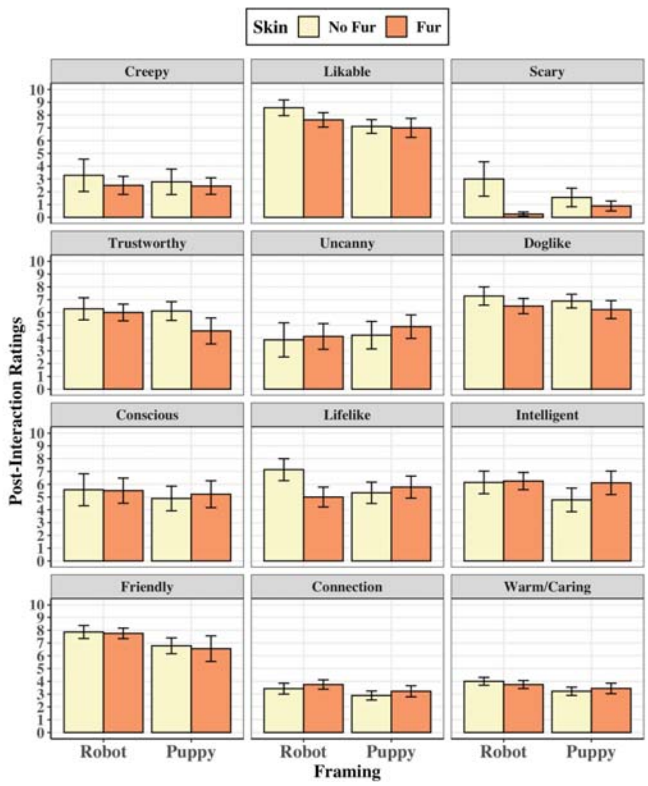

Fig. 5. *Post-interaction ratings for all measures*

We conducted one-way repeated measures ANOVA with Task Command (1-8) as a within-subjects factor on all interactive behavior measures. There was a significant main effect for Task for all measures including Aibo task completions, $F(7, 189) = 15.5$, $p < 0.001$, Aibo task failures, $F(7, 189) = 7.91$, $p < .001$, participant social behaviors, $F(7, 189) = 5.25$, $p < .001$, and task duration, $F(7, 189) = 4.28$, $p < .001$. Post-hoc analyses revealed that the "Come Here" task command elicited the most completions ($M = 5.39$, $SE = 0.79$), failures ($M = 2.89$, $SE = 0.72$), and social behaviors ($M = 9.54$, $SE = 1.72$) compared to the other tasks, $p < .001$ (see Figure 6). In addition, participants spent the most time on the "Come Here" task command ($M = 85.93$ sec, $SE = 19.06$) compared to the other tasks, $p < 0.001$ (see Figure 6).

IV. Discussion

The purpose of the present study was to investigate factors that could influence interaction behaviors with the new Aibo, especially behaviors which could facilitate bonding and long-term social interactions. We hypothesized that participants would respond more positively when Aibo would be framed as puppy rather than a robot (H1). We also hypothesized that participants would respond more positively and socially when Aibo was donned in a fursuit compared to not having fur (H2). Inconsistent with Hypothesis 1, participants were less positive towards an Aibo framed as a puppy compared to an Aibo framed as a robot. Participants thought the "puppy" was less friendly, had a weaker connection with it, and rated it as less warm and caring compared to the "robot" frame. One potential explanation for this result is that framing a robotic dog as a puppy may have raised expectations, which were not met when Aibo was first introduced. A mismatch in expectations is a common finding in social robotics experiments and possibly the cause of the slow adoption of social robotics [22,23]. In addition, background stories provided prior to robot interaction do not always affect attitudes [24]. This finding is also interesting given the marketing materials of Sony, who regularly emails its customers with "Pup-dates" and framed the initial release of Aibo as the "first litter edition". Purchasers of Aibo were also provided with a "Certificate of Adoption" accompanying their recently purchased hardware. Our results would suggest that framing Aibo as a robot may be a better approach overall. Consistent with Hypothesis 2, adding fur had a positive effect: Aibo was considered less scary compared to having no fur. These findings suggest that simple changes to Aibo's appearance, for example, by having it wear a fur suit, may with Aibo when they first encounter the robotic dog. Further, this positive effect of a quick improvement to the appearance lower a possible barrier for human users to develop a bond of Aibo occurred without increasing the ratings of creepiness and uncanniness. However, the participants' ratings of doglikeness did not differ between the fur and the no-fur conditions. Thus, it remains inconclusive as to whether the participants found Aibo with a fur suit less scary specifically because it enhanced Aibo's doglike appearance. Previous research has also demonstrated that adding fur, texture, and skin to a robot has produced beneficial effects [25].

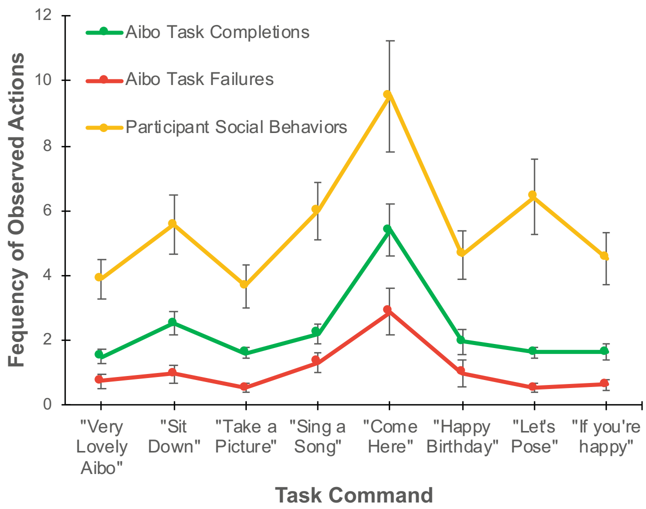

Fig. 6. *Behavioral interactions of Aibo and participants*

Given the positive results found in this study, a fur suit might be a suitable accessory for purchase for Sony's Aibo.

Lastly, the behavioral interaction results showed that the "Come Here" command was the most popular with participants compared to the other commands with the highest number of attempts recorded for this task. Number of completed actions, failures, degree of social behavior, and time spent were all higher than the other tasks. An explanation for this effect may be that "Come Here" is a command often given to real dogs. Most of our participant pool have been pet owners in the past, so this command may have felt more natural than the other commands.

A goal in the development of robotic dogs might be to emulate real dogs and, crucially, the strong bonds that exists between humans and dogs. It is not an accident that a dog is known as a man's best friend. Researchers examining the biological bond between dogs and their owners proposed that this bond has co-evolved through mutual eye-gaze, which stimulates the generation of oxytocin, a neural peptide associated with bonding, in both dogs and people [26]. They demonstrated that when a dog looks at its owner, there is a 300% increase of oxytocin that is generated in the owner. They further demonstrated that this increase in oxytocin leads to increased social behavior from the owner towards the dog, who in turn acts more socially towards his boss. Perhaps robotic dogs one day will be able to emulate and activate this evolutionary loop. Potential evidence to this effect was provided by research that revealed that increasing oxytocin in humans led to more trust and liking of human-like artificial agents [27]. With the deployment of increasingly doglike behaviors, such as patrolling the house as a guard [28], the emulation of a real dog seems possible.

Although in many cases a real dog may be preferable, there are many potential benefits of owning a robot dog. Some people are allergic to real dogs but might still want the experience of a dog. In older adult care settings, for instance, small robotic dogs are being used to facilitate social therapies for older adults living with dementia or Alzheimer's disease. These robots provide similar benefits of living therapy dogs while eliminating some of the drawbacks (e.g., allergies, not enough animals per patient). A robotic dog requires less maintenance and care than a real dog and companies like Ageless Innovations are attempting to offer robotic dogs for older adult therapies at affordable and accessible price points. Future improvements of robotic dogs might make them even more realistic and close approximations of real dogs. Our research provides one step in this direction.

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