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Remote Interspecies Interactions: Improving humans and animals' wellbeing through mobile playful spaces

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Abstract.

Play is an essential activity for both humans and animals as it provides stimulation and favors cognitive, physical and social development. This paper proposes a novel pervasive playful environment that allows hospitalized children to participate in remote interspecies play with dogs in a dog daycare facility, while it also allows the dogs to play by themselves with the pervasive system. The aim of this playful interactive space is to help improving both children's and animal's wellbeing and their relationships by means of technologically mediated play, while creating a solid knowledge base to define the future of pervasive interactive environments for animals.

Keywords. Child Computer Interaction, Animal Computer Interaction, Interactive Environment, Mobile Application, Remote Play.

1. Introduction

Play stands as one of the most natural and inherent behaviors among human and non-human animals. As Huizinga described in his *Homo Ludens,* "Play is older than culture, for culture, however inadequately defined, always presupposes human society, and animals have not waited for man to teach them their playing" [1]. The nature and importance of play have been widely studied and emphasized over the years. One of the main aspects of play is that it is fun, and this is the main source of motivation for all sorts of animals, including humans [2].

In our digital society, we have evolved play, making it even more appealing with the development of technological innovations that allow us to enhance our playful interactions with newer and more varied experiences. From the very first arcade videogames and video consoles with traditional joysticks and gamepads, to the latest playful environments based on Natural User Interfaces (NUIs)

[3–5], the spaces in which playful interactions take place are becoming more and more ubiquitous [6–8]. What remains constant in all these innovations around play is that although its inherent nature may have several purposes that are not yet completely understood [9], it remains essential for cognitive, physical and social development [10], especially in the case of children [10].

Nevertheless, humans are not the only species using technology to improve their playful experiences: non-human animals are also experiencing a digital revolution with emerging research around technology to support animal play [11–16], in what has been coined in previous work by the authors as the *Animal Ludens* revolution [17,18]. Over the past years, the field of Animal Computer Interaction (ACI) [19–21] has gained a lot of attention, proposing the design and development of technology for animal use following a user-centered approach [19]. The main goal of ACI research is to improve the animals' wellbeing by designing suitable technology for them [19]. Playful interactions of animals with technology have been extensively studied [18,22–24], and in the same way that play can be a welfare indicator for animals [2], playful technological interventions have the potential to improve the animals' wellbeing, reduce stress, and provide them with physical and mental stimulation [2,18,22,25]. Technologically mediated play can therefore provide many benefits for both children and animals, such as alleviating stress and anxiety [26,27]. This is especially relevant when these individuals are exposed to high loads of emotional stress and insecurity. On one hand, this is the case of hospitalized children, who can experience social and emotional issues due to the hospitalization experience and the illness itself [28]. On the other hand, there are millions of domestic pets and wild animals in zoos or sanctuaries who have to spend long periods alone [29,30], which might cause them boredom, distress and feelings of isolation. Technology has been used separately in both domains to provide children and animals with mental and physical stimulation to help alleviate these problems [31–35]. However, technology could also be used to support children playing together with animals. In this case, the benefits of playful technology would be added to the positive effects the relationship between animals and patients may have on both actors [36–39]. This would add a completely new range of possibilities to help improve both children's and animals' wellbeing. The only major drawback is that not all hospitalized children can receive the visit of therapy animals or companion animals, due to their clinical condition. Hence, we believe it is essential that technology could allow for remote playful interactions between humans and animals, especially in the case of humans and animals who are unable to spend time together or cannot move from their physical location.

This paper proposes a novel pervasive remote interactive system that allows hospitalized children to play with the dogs in a dog daycare facility by remotely controlling a small robot located in the facility with the dogs, as well as allowing dog to play by themselves with the system. The proposed playful system aims to (1) help improve the children's wellbeing during their hospitalization, (2) foster a healthy relationship between children and animals by means of play, and (3) provide physical and mental stimulation for animals at home, in shelters or in daycare facilities. The contributions of this work are manifold. First, to the best of our knowledge, this is one of the first remotely controlled playful systems designed and developed with an animal-centric focus within the ACI field, allowing children to play remotely with animals physically separated from them by fully controlling the movements of a tangible robot. Secondly, this manuscript presents the design and evaluation of the first pervasive system capable of detecting the dogs' movements to play autonomously with them. Third, an assessment on the impact of the interaction on children's perception of animals as well as on the animals' behaviors has been conducted. This has facilitated the detection of usability issues for both species, which has helped us to advance research within the ACI field by defining future steps and recommendations to improve the development of intelligent playful environments for animals.

2. Related Work

This section contains a review of the current literature regarding interactive playful systems for hospitalized children and animals, highlighting the importance of creating technology to foster human-animal relationships by means of pervasive scenarios that allow for natural interactions.

2.1. Applications for hospitalized children

There have been many studies in the literature in which the use of game technology has helped reduce the negative impact of hospitalization on children and improved their wellbeing inside the hospital [31]. While most of these works use traditional computers and monitors, handheld devices are gaining attention [31]. These devices are more suitable for children with physical discomfort/impediments as they are less physically demanding. In addition, mobile devices allow to create more ubiquitous applications which children could use in their own hospital room.

Several works have studied the combination of animal therapy and games in hospitalized patients observing their positive effects on morale and stress reduction in kids [40]. However, introducing live animals into a hospital is not always possible, and different approaches are needed to provide similar effects on the patients' wellbeing. Several works have replaced real animals with robotic ones, such as a rabbit [41], a parrot [42], a teddy bear [43], a mammoth [33], or cats and dogs [44]. Other studies involve real animals that do not necessarily have to be present at the hospital. *Zootopia* [45] is a tangible-based game that allows children to explore live videos of animals. It consists of a board representing several ecosystems with their respective animals. When the child places a toy with an RFID tag in front of an animal on the board, a live video stream is played showing this animal in a real zoo. However, the camera cannot be controlled, which results in many empty-screen moments. *HabitApp* [46] proposes a tablet-based application that allows children to control the cameras located in a zoo environment to actively observe animals at the children's will. Although these works allow for exploration and observation of real ecosystems outside the hospital in real time, none of them permits direct interaction with the animals or their ecosystem. Being able to remotely play with the animals in real time would add a very powerful new dimension to these activities with regard to improving the children's motivation during their hospital stay [47].

2.2. Playful applications for and with animals

Playful interactions of animals with technology have been one of the main lines of research within ACI [17,34]. Playful ACI has been defined as a sequence of interactions between an animal and a technological stimuli that are not externally rewarding for the animal but produce positive change in its state [17,22]. Along this manuscript, we frame our research within this definition of playful, which aligns with the interpretations of Huizinga [1], Callois [48] and Burghart [49].

Technologically mediated playful experiences for animals usually involve a human participant who either controls the activity or plays together with the animal. Felino [24] and Cat Cat Revolution [50] proposed a tablet-based game for cats in which the animal has to catch some creatures that appear on the screen. The human can adapt the elements that appear in the game to the cat's preferences [24] or move them around to play with the animal [50]. A similar approach is the use of tablet-based applications for zoo enrichment. The *Apps for Apes* [51] project consists of a set of applications that orangutans can play with on a tablet. However, a zookeeper outside the enclosure has to hold the tablet for the orangutan and the interaction is therefore quite limited. The *Kinecting with Orangutans* [12] project goes one step further and allows the orangutans to play with elements projected onto the ground of their enclosure, using projections and depth sensors, thus allowing the animal to interact more naturally. Non-wearable tracking systems have been proven very useful to allow natural interactions of the animals within a more pervasive game scenario, such as detecting playful behaviors of cats towards digital and robotic stimuli [12,52], or tracking orangutans movements of a tangible device [13]. *Purrfect crime* [53] also proposed the use of depth sensors and projections to create a digital game for cats and humans, in which both have to catch digital birds projected onto the ground. Most of these works require the human and the animal to be in the same physical space. One of the first works to propose an animal-centric design for remote interactions with animals was *Rover@Home* [54], which evaluated a remote clicker training routine for dogs. This work highlighted the opportunity of creating future playful systems based on animal-centric remote interactions. While there have been abundant commercially design devices for remote pet-human interaction [55–57], fewer ACI works have emerged in this context grounded on animal-centric practices. As an example, in the *Playing with Pigs* project [58], the human uses a tablet application to move a visual digital element that appears on a wall-screen in a pig enclosure. The goal is that the pig touches the digital elements with its snout and reaches a desired target area. The human does not need to be physically present with the pigs to play with them. However, although this was a novel idea, it has not been developed further. Another example is *LonelyDog@Home* [35], which allowed a human to connect over the internet to a web camera and remotely feed her dog, as well as throw a ball to the dog. Although the system in [35] was one of the first works within ACI and allowed remote interaction, the playful activity was quite limited, as the human could only throw the ball towards the same place all the time. A more recent work regarding dog-human remote interaction proposes the use of video calls to mediate the communication between the dog and the owner. However, the interaction again is limited to the human just being able to release a treat while observing the animal [59].

In previous work by the authors, a need has been identified to evolve interactive spaces for animals and humans towards a more pervasive solution [17,52] in which the animal can move freely around the space and the playful interactions can be more varied. This would allow the animal to interact with the system in a more spontaneous and unconstrained way, working towards the goal of improving the animals' welfare by allowing playful behaviors as a rewarding experience on its own [2].

Regarding the nature of the playful experience, there are studies highlighting some animal species such as dogs or cats showing interest towards tangible devices [14,15]. As the current digital experiences do not offer these affordances, the use of tangible devices for animals within these playful interactive systems reveals as a promising opportunity. In fact, there has been great interest in studying animals' interactions with robotic devices, especially in the context of behavioral research [60,61]. In the context or dog-robot interaction, studies have shown that if a humanlike robot behaves socially, dogs are more keen to interact with it [62], and with non-human-like robots, further studies suggest that dogs form expectations about an unfamiliar moving object within a short period of time, recognizing some social aspects of the robot's behavior [63,64].

2.3. Designing to improve relationships between humans and animals

ACI research has recently begun to explore how technology could help to improve the relationships between humans and animals [12,24,65,66]. Several works have studied the perceptions of humans towards animals' interactions with technology in different contexts. For instance, discovering how pet owners perceive their dogs' reactions towards technological devices can help to raise awareness of good or bad practices in digital interactions of animals with technology [67,68]. On the other hand, animal conservation organizations aim to provide empathic responses of visitors in order to foster interest in wildlife, and technological installations have shown to be promising in this regard [12,69]. The design of playful technology for animals with an animal-centered design perspective has also allowed humans to empathize more with the animal, helping to create stronger concern and bonds. This has been shown not only when the designers of the playful scenario are experienced researchers [11,14,23], but also when the human has no previous design experience at all, such as children [65]. Humans have described these playful activities with animals, from their design [23,65] to their realization [12,50], as "*useful spaces to reinforce their relationships and to create new forms of communication with the animal*" [50]. As the world is becoming more interconnected, these communicative spaces do not need to happen in the same physical space. By expanding the horizon of playful shared spaces towards remote and pervasive scenarios, the benefits of such playful experiences could be extended to other populations that have physical constraints. In the case of playful experiences for humans and animals, remote scenarios would allow them to experience a bonding activity without the limitation of being together in the same place.

3. Technological Platform

This work proposes the design, development and evaluation of a remote playful system in which children can control a tangible robot to play with an animal in a different location. Additionally, on the animal side of the interaction, a pervasive system has also been developed capable of controlling the robot autonomously to play with the dog without human intervention.

The selected technologies for both the human and the animal in the proposed remote playful game should be aimed at facilitating the interaction by adapting to the user's physical and cognitive characteristics. In the case of children, previous work by the authors showed that within a co-design activity children envisioned technologically mediated games with animals as a playful scenario in which the child was in control of a robotic element the animal could play with [65]. The children's user interface will therefore consist of a mobile application they could use even from their own bed at the hospital. In the case of animals, previous work has shown that purely digital stimuli might not have all the effect that tangible elements can provide for some species [14,15,70], such as grabbing, touching, biting, etc. In this regard, our proposed system will use a tangible robotic ball to interact with the animal. In addition, for the non-human mediated game between the system and the dog, a non-wearable tracking system would allow the animal to behave more freely and with more spontaneity [52,71]. For this, a non-wearable tracking system capable of detecting the dog's movements has been implemented.

The playful remote system proposed and evaluated in this paper consists of two separate applications that communicate remotely over the network (see Figure 1). We deployed a Sphero® robot and a Microsoft Kinect® v2 sensor in the dog daycare facility to record the play area and track the dogs' movements. A .NET streaming server was developed to record images from the sensor using the Microsoft Kinect® SDK 2.0 and C#. A Universal Windows Platform application was also developed using the Sphero® SDK for UWP, which allows any available Sphero® robots around to be discovered, connected and sent basic commands via Bluetooth. The Sphero® UWP controlling application exposes a UWP AppService on the computer on which it runs, with which the .NET streaming server can communicate with to request its services when running on the same machine. On the client side, we developed an Android application that connects to the streaming server from any location on the network, receiving and displaying real time images from the daycare facility on the screen of the mobile device. This Android application is installed on a mobile phone and used by children at the hospital. Once the client application connects to the server and starts receiving images, it displays them on the screen along with four buttons to control the Sphero® robot (see Figure 2). When the user presses a button on the Android application connected to the server, the corresponding command is sent to the server at the dog facility in real time. The server then transfers the command to the Sphero® AppService requesting it to move the robot with the selected command. The Sphero UWP application then communicates with the robot via Bluetooth and sends the moving command to it (see Figure 3). The experienced average delay of the system is 280 ms (σ = 132.5 ms).

4. Interspecies Playful Interactions Study

This section describes the interspecies study conducted to evaluate the experience of both children and dogs when interacting with the system, for which four research questions were defined as follows:

RQA: How is the interspecies remote game with dogs perceived by the children?

RQB: Could remote playful systems help improve human awareness and human-animal relationships?

RQC: How do dogs behave when interacting with the system in each modality?

RQD: How could interspecies remote games be improved to support children and dogs wellbeing?

4.1. Observational Study on Children

This section describes the observational study conducted on hospitalized children using the remote interactive application to play with a dog. The aim was to evaluate the playful experience of children in terms of usability, enjoyment and effectivity in terms of improving the animal-human bond.

4.1.1. Participants

The participants were hospitalized children from the *Hospital Universitari i Politècnic La Fe* in Valencia, Spain. The hospital has its own school in the pediatric wing to which children from primary and secondary school can attend, although the pediatric oncology patients usually need to stay within a designated area. The sessions of this study were therefore conducted either in the pediatric school room or in the child's own room at the hospital, having either the child and/or guardians' agreement to participate. The children who participated were those attending the pediatric school in the days in which the experiment took place, and children in pediatric oncology with prior assessment of their medical state. The only requirement to participate in the study was being able to use the application. Twenty-one children participated in the study (11 girls and 10 boys, 15 children from pediatric school and 6 children from pediatric oncology), with ages from 4 to 15 years old ($\bar{x} = 9.43$, $\sigma = 2.66$).

4.1.2. Methodology and Procedure

Each child performed the activity individually with the researcher. The sessions lasted approximately 10-15 minutes, according to the child's interest in the system and the time needed to answer the postquestionnaire. The decision about the duration of the sessions was based on a tradeoff between exploring how children and dogs would react to the system without any previous training to observe their spontaneous reactions and assess whether they would like to play again. While longer sessions would have allowed the participants to become more familiar with the system, we aimed towards maintaining the novelty factor while adapting to the hospital routines. At the start of the session, the researcher briefly introduced the activity to the child, explaining that she was going to control a robot using a mobile application in order to play with a real dog located in a daycare facility nearby. Once the researcher had introduced the activity, the child received the mobile phone with the application already connected to the server and streaming images from the dog facility. Each child was allowed to use the application for 5-10 minutes, with no initial training, and was then encouraged to explore what happened when she pressed the buttons displayed on screen. While the child was using the mobile application, the researcher filled in an observational template, also noting any verbal feedback the child might give. We adopted a non-trained approach in order to observe children's spontaneous response when they discover the first time that the interaction is happening in real time, as well as to identify usability issues and familiarization times to improve future iterations of the system.

After the game, the children filled in a brief postquestionnaire about the animal and the activity, consisting of 5-point Likert questions based on the *Fun Toolkit* questionnaire [72] (Figure 4). These questions identified usability issues, the children's perceptions regarding the animal, assessing whether they enjoyed the game and if they thought the game would be a positive experience for the animal as well. Table 1 shows a summary of the questions the children answered after the activity.

4.1.3. Observational Results

One of the first observations of most of the children was their positive surprise when they saw the animal moving and reacting to the robot's movements they were performing. Even after the activity had been explained to them, describing that the dogs were actually in the dog facility so that they could play with them, some children asked again to confirm whether the video was being received in real time. One of the children's most frequent questions was the name of the dogs they were playing with, and questions such as “*What is the dog doing there?*’ or “*Are there more dogs around?*’. Overall, the children easily learned how to control the robot with precision. Only three children were observed to have issues with the application due to their age, physical condition or personal preferences. One of these was four years old and was the youngest in the study, another had a restricting physical condition and required an assistant to hold the mobile phone for her, while the last reported she did not like dogs and showed little interest in the activity in general. Few issues regarding the design of the application were reported by the children during the activity, and these mostly involved difficulties in controlling the robot when it went out of the camera's field of view. Only one child complained about the delay in the image and another reported that the robot moved too slowly. Only five children were observed to be irritated or expressed a certain degree of annoyance when the dogs did not react as they were expecting. In spite of this, they kept trying to move the robot to capture the attention of the dog, or stopped playing with the robot and just observed the dogs move around. Most of the children did not complain about the dogs' behavior and even when the dogs did not play with the robot the children were keen to keep trying new movements to make the dog play.

Almost all the children showed signs of joy and amusement from the beginning of the activity: smiling, laughing, commenting aloud what the dogs were doing, calling the animals by their names and talking to them as if they were in the same space, etc. In a few cases the children were more neutral in their reactions: one was not interested in the activity, another was highly concentrated, another did not seem excited as she was playing with a dog that was not very playful, and in one case one child was experiencing physical discomfort due to her condition.

The researcher rated each child's perceived interest in the activity on a 5-point scale. Overall interest in the activity was really high, with an average of 4.5 points (σ = 0.75). These results can be compared to children's answers to Q1 in the postquestionnaire (Section 4.1.4, Table 2), showing that they were highly motivated towards the activity and enjoyed the experience.

4.1.4. Questionnaire Results

After playing remotely with the dog using the Android application to control the Sphero robot, the children were asked to fill in a brief postquestionnaire containing eleven Likert scale questions and one open answer question. Figure 5 shows the results of the Likert scale questions listed in Table 1, while Table 2 contains the mode, mean and standard deviation for each question. It can be observed that more than 50% of the answers to all the questions were rated with the highest scores (4 or 5), with low standard deviations (< 1.5 points). Additionally, we performed a binomial test for the hypothesis H_0: *"the number of children answering 4 or 5 is equal to the number of children answering 1, 2 or 3"*, with p-values reported in Table 2 rejecting this null hypothesis for the majority of the questions. This means that for questions Q1, Q2, Q5, Q6, Q7, Q[illegible] and Q[illegible], more than 50% of children answered positively with statistical significance.

The first three questions were intended to assess the children's overall enjoyment of the activity. In Q1, they were asked to rate their enjoyment in playing with the animal with the mobile application. 80.96% showed great enthusiasm for the activity and rated their enjoyment very positively, with either four (Very good) or five (Great) points. In fact, none of the children rated their enjoyment with one (Bad) or two (Not great) points, even when the child was seen to be distracted or not very interested in the activity. When they were asked whether they would like to play with the dog again using the remote mobile application (Q2), their answers were even more positive than in Q1. Most were willing to repeat the playful activity, with 85.72% of the children reporting that they would really like to play with the dog again, with scores of five (A lot) and four (Quite). Only two said they would not like to repeat the experience. One of these children reported lower levels of enjoyment in Q1 than the rest of the participants, and showed poor interest in the activity. The other participant who was not willing to play again was very young – 4 years old – and although she showed great interest in the activity, the researcher reported some difficulties in the interaction. Q3 was meant to assess the collaborative aspect of the activity, asking the children whether they would like to play this interspecies game with other children. Socialization is a very important factor in hospitalized children, and mobile environments are ideal for having shared spaces in which they can create a positive hospital experience and reduce their sense of isolation [28]. In this regard, 61.91% of the children said that they would like to share this experience with other children. Only three (14.29%) reported they would prefer not to play with other children. One of these had reported she did not want to play the game again, and the researcher also noted she did not seem interested in the activity. However, the remaining two children expressed a lot of excitement about playing with the dogs again, preferring to have the activity just for themselves.

Questions Q4 to Q10 were aimed at assessing whether children considered the game to be a positive experience for the animal and how the playful interactions with dogs affected their relationship with and perception of the animals. The children were asked whether they considered the animal enjoyed playing with the robot (Q4), with 52.38% rating the animals' enjoyment with five (A lot) and four (Quite) points. This was one of the questions with the highest variability in the answers ($\sigma = 1.43$), and could be explained by the dog's behavior in each case. If the children saw the dog was not interested in the game, without directly interacting with the robot or looking in the opposite direction, they were more likely to evaluate this response as low enjoyment. Some children gave as reason for their answer that "the dog was not paying attention to the robotic ball" or that "it depends on the personality of the dog, some of them might like to play with this ball while others not", showing their awareness of the animal's preferences and needs. It is interesting to note that, although some children perceived that the animal they were playing with did not seem to be interested in the activity, 76.19% believed the activity was beneficial for the animal (Q5). None of the children considered this activity bad for the animal in any degree. The participants showed a lot of interest in knowing more about the animals they were playing with (Q6), with 85.71% rating this question with four or five points. The children said they would like to know if the animal liked to play, what type of character and personality it had, e.g. if it behaved well in its daily routine, and what does it like to do and play with when it is not playing with the robot. The children reported whether they would like to have more animals playing together with the robot at the same time (Q7). In contrast to the results of Q3, on sharing this activity with more children, they preferred to have more animals playing, with 90.48% of the answers rated with 4 or 5 points.

Questions Q8 to Q10 focused on the children’s perception of the animal in terms of likeability, friendliness and intelligence, respectively. Overall, most of the children liked the dog from “quite” (19.05%) to “a lot” (71.43%), and considered the dog to be quite (14.29%) or very friendly (71.43%). Their perceptions of the dogs’ intelligence were a bit lower than their friendliness, with 52.38% of children reporting the animal to be very intelligent or at least quite intelligent (19.05%).

The last Likert scale question (Q11) addressed the application’s usability issues, asking about the perceived difficulty of moving the robot to the desired place. Overall, 71.43% of the children reported that controlling the robot was either easy, very easy or “super” easy (rating this question from 3 to 5 points). Of the children who considered it difficult or somewhat difficult, one reported the delay in the response as the main issue, and two explained that the robot had got stuck where they could not see it, e.g. in a corner, and could not easily return it to the visible area. Another child reported the interaction as difficult because he considered the robot was slow and he wanted it to move faster. No perceivable difficulty in the interaction was observed by the researcher in the remaining cases, and these children did not give the reasons for their answer either.

Lastly, the questionnaire gave the children an open-answer question (Q12) about what they considered important to include in the game to make it more fun and engaging, either for themselves or for the animals. Some of the suggestions were to have light, sounds and even smells on the robot to make it more interesting for the animal. Another suggestion was that they would like to hear the animals in addition to seeing them on the screen. Several children said they would love to see other animals in the daycare facility, not just the ones they are playing with, as well as having a wider camera angle or even the camera installed inside the robotic ball to see the dogs better. A couple of children suggested feeding the animal by either using the robotic ball as a challenge to get a food reward, or by being able to move the food around and give it to the animal. Some of them wanted the animal to be more playful, follow the robot, or even take the robot in its mouth. Various children reported they would like to try with different toys, such as a dog bone, while others suggested that the robot should be faster, bigger and able to jump.

4.2. Animal Computer Interaction for Playful Interactive Environments

Play is an essential activity for all animal species, and it can help to improve the mental and physical wellbeing of animals in special circumstances. In this regard, technology can play a crucial role by creating suitable interactive spaces for animals to support playful interactions that can help to improve their wellbeing [18]. The field of ACI is making a big effort to design such suitable interactive scenarios for humans and animals playing together, or for animals playing by themselves.

In order to advance research regarding how technology could be used to create suitable technology for animal play, this work reviews the design, development and evaluation of two modalities of a playful interactive system for dogs. First, a remote system in which children control a tangible robot to play with a dog in a different location, followed by a pervasive system capable of controlling the robot autonomously to play with the dog without human intervention. The aim of having two interactive modalities for the dogs was to assess the suitability of future playful autonomous systems for animals that dogs could use without human intervention. For this purpose, we first need to evaluate whether dogs behave differently when the system is controlled by a human as opposed to when it is autonomously managed, and assess what changes should be made to improve the dogs' experience. This section compares the human-controlled system with the pervasive and autonomous system for dogs, with the aim of detecting usability issues, preferences and behavioral patterns that would help researchers to design better autonomous playful systems for dogs. This analysis has allowed identifying the next steps to be carried out for the development of intelligent playful environments for animals that give them engaging and adaptive experiences, helping to advance research in ACI.

4.2.1. Participants

The animal participants were dogs from *Buma's Doggy Daycare*, a local dog daycare facility in which dog owners can leave their dogs during working hours or holidays. All the dogs spend their time together inside the center, moving freely around a covered area of approximately 60 square meters. Of the 25 dogs that were introduced to the robot, only 2 were immediately let out of the interactive space as they showed signs of being afraid of the device (averting gaze, whimpering [73]). A total of 14 dogs tried both the remote and the pervasive modalities and were considered for the observational study, excluding from this study the remaining 11 dogs who only participated in either the child-controlled or the pervasive modality. The demographics of the dog participants are reported in Table 3.

The study took place in a delimited play area of 4 meters long and 1.5 meters wide (see Figure 6). The robot was placed inside the area, while a Microsoft Kinect sensor with a tripod was placed outside to record as much space as possible. Several plastic tubes were fixed to the ground over irregular spaces to prevent the ball from getting stuck in a corner or behind the dogs' beds.

4.2.2. Methodology and Procedure

In the remote interactive modality, one or two dogs participated in each session playing with a child, depending on the dogs' observed reactions. The robotic ball was placed inside the play area before the session started, and the dog participating was encouraged to enter the interactive space. Whenever a dog showed signs of distress or was seen to want to leave the interactive area, it was let outside and another took its place. Each session lasted for 5-10 minutes and was video recorded for further annotation to gather observational feedback. The set-up is shown in Figure 6.

The same procedure was followed for the autonomous interactive system: 5-10 minute sessions, video recorded for later annotation. The matter of consent has been widely discussed within animal centered practices [74,75], and within this study we aimed to cover several of its aspects including: working in the dog's habitual context, having the caregiver observing, no training nor reinforcing behaviors, and allowing the animal to withdraw. Dogs were not introduced to the technology in order to observe whether the proposed interaction modality seemed suitable, meaning that the dogs could be able to use and learn how to interact with the system without human intervention. Regarding withdrawal, the activity was stopped as soon as the dog showed signs of wanting to leave the interactive space. In addition, as the experiment took place during working hours of the daycare facility, external factors could make the dog's attention shift away from the interaction. In this regard, we allowed a period to make sure the dogs could engage again with the robot if they wanted to. After 2-3 minutes of the dog not showing any interest in the device or even paying attention to noises or movements outside of this area, we opened the door so that the dog could walk outside the tracked area if needed.

Aligned with the idea of consent, ACI research takes careful consideration of the animal-computer interaction loop [76,77], putting strong efforts in avoiding human interpretations of both the animal's intentions towards the system and the animal's interpretations of its signals [14,78]. Inevitably, in the remotely control modality children interpreted the intentions of the dogs in order to react and move the robot according to what they envisioned the dog would prefer or expect. However, in the pervasive modality in which the system controls the robot, we have aimed towards a neutral system capable of reacting to the dog's movements without any intentional judgement. We cannot assess whether the dog perceives the activity differently between the remote or the autonomous system, nor if he knows there is a human controlling the system in the remote mode. Previous research has shown that the interactive behavior of a robot seems to evoke different responses from the dog [62–64]. This work thus studies dogs' spontaneous reactions towards a robot, analyzing whether there are differences in dogs' behaviors to assess how the system should be adapted in the future to be more engaging for the dog. The observed behaviors are described further in section 4.2.4, while Table 3 details the number of times each dog showed a specific behavior during each of the two proposed interactive modalities.

4.2.3. Pervasive Interactive Playful Environments for Dogs

Previous work in ACI has explored non-wearable tracking systems for animals for play [15,52,53] or training purposes [79]. These studies produced systems capable of detecting different contextual information from the animal, ranging in complexity from simply detecting the animal's position [53] to classifying its body posture and body parts [52,71,79] and even its orientation/field of view [15,52]. As non-wearable tracking of an animal allows more natural and spontaneous interactions, this was the approach used in this study. Detecting the animals' movements and behavior without wearable devices generally requires supervised or semi-supervised training [71,79] or imposes strong restrictions on the physical location, which has to be emptied of other objects that could obstruct or confuse the tracking algorithm. This makes it more difficult to adapt the system to different individuals and the person deploying the system must be experienced. The installation described in this study was aimed to accommodate to different dog participants each day, which made a supervised/semi-supervised approach unfeasible. Instead, an unsupervised interactive system capable of detecting only the animal's movements was preferred, as it would provide information on whether basic contextual information could provide similar results to the human-controlled modality.

The Microsoft Kinect sensor used in the study provides both color and depth streams (Figure 7a). The pervasive interactive system processes the streams in real time to detect the dog's and robot's movements, and make the robot react accordingly. In this modality, the system should be able to detect both the dog and the robot device, and send commands to the robot to move it around the play area according to the dog’s movements. The Microsoft Kinect sensor was placed in a higher position than in Figure 6 in order to get a better view, covering a smaller interaction area but reducing the possibility of the robot being hidden behind the dog or an object. The first step of the image-processing algorithm consists of applying a background subtractor based on movement detection, for which the *BackgroundSubtractorMOG2* algorithm from the EmguCV package for C# was used. Once the background substractor has been applied, the remaining image shows the depth contour of the elements that have moved from the previous frame to the current one (Figure 7b). The robot’s and the dog’s contours must then be identified, assuming for the sake of simplicity that the bigger contour would be the dog’s. In addition, at the start of the session the system allowed to configure the size thresholds of the robot and the dog to accommodate for minimal variations in the set-up height or lighting conditions that could affect the detection.

Once the activity started, the behavior of the unsupervised interactive system and the decisions taken by the system for controlling the robot were defined as follows: if the dog was not detected within the tracked area, the system sent a “spin” command to the robotic ball in order to make it rotate once around its axis and try to capture the attention of the dog. This action was repeated every few seconds until the dog was detected. When both the dog and the robot were detected within the tracked area, an orientation vector was traced between them, and the system sent a “move” command to the robot either to move it away or towards the dog, following the orientation vector between them. When neither the dog nor the robot was visible, a “random move” command was sent to the robot in case it was stuck in a hidden area, i.e. the robot will randomly choose a direction to move towards it without considering the dog’s position.

In addition, a more active approach was also implemented for dogs who did not seem interested in the normal approach described above, as the dog behavioral expert suggested that some dogs might need more dynamic robot movements to get their attention. This approach was activated by the researcher after observing the dog’s initial behavior with the device. It consisted of the same rules as in the normal approach, with a much shorter delay between the robot’s movements, and when the dog was not detected, the system sent a “random move” command instead of a “spin” command to the robot.

4.2.4. Observational Results

In general, even though the remote playful modality with children usually obtained a higher level of interactivity from the dogs, the dogs’ behavioral patterns were similar in both modalities: if a dog was not interested in the activity, i.e. relaxed position but lying down, not staring at the robot or even looking outside of the play area [73], it would not play in either the remote or pervasive modality. On the other hand, if a dog was seen to be interested in the activity, showing a playful attitude to the robot (play bow, play slap, bumping the robot [80]), it would interact in either the remote or the pervasive modality. In the remote modality, in which a child was controlling the robot, the interaction was usually more fluid and regular over time, as the child was better able to adapt to the dog’s reactions. Four different behavioral patterns were identified in the sessions:

- *Passive behavior*: dogs showing passive behavior do not show interest in the robot, staying in a calm and relaxed posture. In this scenario, the dog is either exploring the area and looking somewhere else than the robot (see Figure 8b), avoiding eye contact with the robot, which could be an indicator that it wants to avoid problems [73], or while staying perfectly calm it may not pay attention to the device, e.g. even when the robot touches the dog, it may not get any response.
- *Alert behavior*: alert behavior has been defined as the dog being aware of the robot, as it keeps eye contact with the device, however there are no signs of playful behavior or invitations to play on the dog’s part. Instead, the dog might change its focus of interest between the robot and the environment, always keeping the robot in view, and usually moving opposite the robot when the device approaches (evasive behavior [73]).
- *Playful behavior*: In this behavioral pattern, the dog shows clear signs of enjoyment and playful behavior, such as wagging its tail or doing a play bow/play invitation towards the robot. Usually, the dynamics of play within this pattern are respectful and gentle. The dog looks at the robot while it moves, following it if it goes away or moving back if it approaches [80]. Signs of excitement, e.g. jumping or play slap [80], are shown when the robot moves, along with some barking. When the robot does not move at all, the dog stares at it expectantly for a while. However, if the robot does not move for a long period of time, the dog walks away and focuses on something else. When

the robot starts moving again, even with just a gentle spin command to capture the dog's attention, the dog comes back again and restarts the playful interaction process. During the interaction, the dog might touch the robot repeatedly with its front paws. In several cases, the dog was seen to try to move the robot with its snout [81]. Other examples of playful behavior include the dog trying to grab the robot with its mouth, or actually grabbing it and walking away. In this latter case, pervasive and ubiquitous spaces would allow a greater area of interaction to be defined, giving more control to the dogs in terms of when and where they prefer to play, and potentially even increasing the interest and attention of other dogs in the technology.

- *Intense playful behavior*: playful behaviors can happen with more or less intensity depending on the dog's age, character and mood. It was observed that some dogs displayed a more energetic play with the robot, always showing signs of playful behaviors as in the previous pattern described, e.g. wagging the tail, play bow, jumping, paw lifting [80]. However, in this more intense play, other behaviors arose, such as jumping or running towards the robot (exaggerated approach [80]), touching it repeatedly (see Figure 8a), throwing or kicking the robot away with their front paws, and trying to grab it with their mouth repeatedly [80]. In this pattern of play, the dog did not wait much for the robot to move but instead actively started kicking the robot the moment it showed some minimal movement. In the remote playful activity, this meant that the child did not have a lot of control over the robot, as the dog was constantly moving it from one place to another. However, the children seemed to also enjoy this kind of interaction.

Table 3 contains a summary of the behavioral patterns observed for each dog in each of the two interactive modalities, indicating the number of times the dog displayed each behavioral pattern. Only three dogs displayed a passive behavior throughout the whole session, while the behavior of five dogs shifted between a passive and an alert state. Regarding the playful behaviors, five dogs displayed a playful behavior at least once, while one dog displayed an intense playful behavior repeatedly. Overall, the total number of times each behavioral pattern was displayed was 28 times for passive behaviors, 35 times for an alert behavior, 21 times for playful behavior, and 6 times for intense play.

4.3. Threats to validity

Although this study obtained interesting results, several precautions must be taken before generalizing these results to other contexts.

On one hand, children's age and needs might have affected the way in which they understood the questionnaire, and we tried to minimize this issue having a researcher with a strong background in psychology performing the observation and evaluation phase. This allowed her to adapt the questions to make sure children understood them, while maintaining the neutrality and objectivity in both questions and answers. On the other hand, observational results would have been stronger with a second observer, however due to the nature and scenario in which the study took place, we prioritized the creation of a comfortable space for the child in which they understood the study as a ludic activity for them rather than feeling evaluated. For future studies, the design of the observational evaluation could be aimed for a long-term period in which the novelty factor and the children's intrinsic motivation could be assessed [82]. In this design, parents, nurses or teachers could be taught to be the ones assessing children's state and observations, creating a more familiar environment for the child while having several independent observers.

The presence of new people, such as researchers and new elements in their environment, i.e. the technical installation and devices, usually triggered the dogs' interest. This excitement and interest could have diverted them from the playful activity towards the new things that were happening around them. In addition, the dog facility was open to the public during the study sessions, which occasionally meant that dog owners came to the facility to leave or collect their pets. This was also another source of distraction, as most of the dogs were curious and approached the entrance, which in turn would get the attention of the rest of the group. Another aspect to consider was the dogs' mood and their degree of familiarity with the other dogs at the facility on that day.

Some dogs required a brief introduction to the device, as their initial reaction was to avoid the robot, displaying behaviors of avoidance as they will do with another animal (averting gaze, evasive behavior, walking away [73]). In these situations, two approaches could be followed. In the first attempt, the researcher took the robot in her hand and showed it to the dog, as if it were a regular plastic ball, letting the dog sniff it and become familiar with it. If this attempt was unsuccessful, the dog behavioral expert, who was known to the dogs, stood near to them during the activity to create a safe space for the animal. The first approach was successful for a few dogs, and could be included as part of the procedure to introduce the activity to shy or fearful individuals. The second approach did not produce any changes in the behavior of the dog, meaning that their interaction was the same, whether or not a human was present. It is hypothesized that dogs showing an *alert* behavioral pattern would probably need more time to become familiar with the robot.

Finally, the area of interaction was delimited in order to explore how well dogs managed to play individually or with another dog, and to ensure that children could see the dog at all times while interacting. For further implementations, the tracking and recording areas could be increased so that dogs can play unbounded within a larger space while children can see them from different angles. We believe all these threats to validity could be addressed by deploying a more permanent installation in the dog facility, which would allow the dogs to acclimatize to this new environment and in time they could even start to interact with the robot at their own will.

5. Discussion

5.1. Remote mobile games for children's wellbeing

The main goal of this work was to provide a mobile interactive experience that has the potential to improve the wellbeing of both children and animals while creating a stronger bond and sense of awareness in humans towards other species. Regarding the research question RQA about children's perceptions of the interspecies remote game, after the observational results, and in light of the postquestionnaire results, the described remote playful application was found to be successful at providing an enjoyable and fun experience for children. During the sessions, the children were observed to be concentrated on the activity and showing physical signs of enjoyment, and they reported very positive results when asked about the experience and whether they would like to play with the animal again. Incorporating this activity into the daily routine of hospitalized children could thus offer an opportunity to mitigate the stress produced by being hospitalized. Psychological assessment could be conducted in order to quantify the effects of this intervention on hospitalized children. This remote interactive experience could also be explored as a "distraction therapy" for pain or anxiety in child patients with high levels of pain or discomfort, or during painful procedures such as lumbar puncture, in which children need to stay still and avoid thinking about the procedure itself. As reported in the questionnaire results, the majority of children said they would like to play with the animal again and with other children, which shows potential for the activity to become a social scenario. Communication and socialization within the hospital environment are very important aspects to improve children's mental wellbeing during their stay [28], especially in the case of long-term hospitalizations. These long stays at the hospital can produce emotional issues in children, sometimes due to feelings of loneliness or isolation for being separated from their friends or family [46,83]. In this regard, the remote interaction with the animal could be considered as a social activity in which the child interacts with another being. Moreover, the social dimension could be enhanced by creating a shared experience among hospitalized children that could help them feel more connected to their new friends at the hospital. These social mobile environments could be deployed in several rooms at the hospital. Each child could be given a tablet or mobile device to connect to the streaming server and one would have control of the robotic device at a time, in a similar fashion as the authors proposed in [46]. In addition, chatting features could be added to the application to allow direct communication between children in different rooms. Another scenario could be to have multiple robot devices, each one controlled by a different child, all playing together at the same time with several dogs.

The sessions conducted with child patients from the oncology ward had to be conducted inside the child's room. This created a different set-up of the activity in which the parents and/or hospital teachers were also present during the session, and played an important and unexpected role in the interaction. The parents were able to encourage their children to interact with the dog in different ways, sharing an enjoyable experience at the hospital together. This activity could help not only the children, but also their parents, who are also under huge emotional pressure and stress [84]. Observing their children enjoy themselves and forgetting their condition for a while could have a positive impact not only on the children, but also on their parents in terms of reducing stress and anxiety. This, in turn, could help the children to improve their emotional wellbeing, as parents' feelings can affect the way in which children perceive their state. In future evaluations of the system, parents' insights and perceptions about their children's experience should be considered - with expert advice and careful design in order to avoid biases. This could help to add valuable information about the child's experience, preferences and effect of the technology. This will be especially interesting in the case of long-term evaluations to assess the children's evolution.

5.2. Improving the human-animal relationship

The research question RQB proposed in this study aimed to assess whether remote playful activities could help improve human awareness and human-animal relationships. In previous work by the authors, it was observed that children's perceptions about an animal improved after the design of an interspecies playful activity, and they were able to reflect on their designs to highlight potential pitfalls or scenarios that might not be as fun for the animals as it was for them [65]. Our present study corroborates the results of our previous work: the children's answers showed positive likeability and perceived friendliness in the animals, and a will to learn more about the species and the animals playing with them. Different responses from the dog due to the animal's personality or mood at the time of the interaction could greatly affect the children's perceptions. However, in general they were very motivated towards exploring and trying different interactions to see if they could get the attention of the dog, even in the cases in which the dogs were not displaying playful behaviors. In addition, the children were able to acknowledge the cases in which dogs did not show interest in the game, but they could also perceive that animals need mental and physical stimulation for their wellbeing. Hence, they were motivated towards providing suggestions to improve the game or looking for reasons why the dogs preferred not to interact. In order to quantitatively measure how accurate children are when assessing the dog's interest, future evaluations could correlate children's perceptions of animals' behaviors with the actual state of the animal.

The children were also capable of reflecting on the different implications this game could have for the animal in comparison to the experience they were having as human participants controlling the robot device. These design activities could thus be used as a tool to help raise awareness, foster critical thinking and improve relationships with different animal species. There is an opportunity to create playful learning activities that could also help to increase empathy by sharing an experience and learning about the animals' behavior and personality. This could also be envisioned for non-domestic animal species, such as endangered species in zoos or sanctuaries, to which children do not have easy access, and remote interactive scenarios could be a way of bringing them closer.

The level of awareness of the answers to Q12 also supports the postquestionnaire results. The children were capable of making suggestions to improve not only their personal experience of playing with the dog, but they were also thinking about the animals' wellbeing and enjoyment. Many of their suggestions addressed the addition of new features to the robot or elements to the game in an attempt to make it more fun for the animal. While children's suggestion of a food delivering robot ball could be interesting to at least some dogs, this option should be considered carefully. The aim should be that the animal plays as a reward in itself; however, food-based interactions could be carefully introduced to motivate those dogs initially more reluctant to explore the system. Children were also able to reflect on the dogs' reactions in order to think about what kind of interactions could be more interesting for the animal. One of the children even reported that "*as the personality of the animal determines whether the dog would interact or not, it would be useful to have two dogs playing at the same time, one of them who likes to play and the other one who does not. In that way, the dog that plays could motivate the other dog to start playing as well, and at least the child who was controlling the robot could play with one of the dogs*". Although this child's assumption that the dog's personality may condition its behavior towards the robot, which has not been studied in-depth yet, it is surprising that this scenario proposed by a child participant was being used throughout the experiment whenever the dog expert detected that the dog showed boredom or distress. In such cases, either the dog was let out, or another dog entered the interactive area to see whether its company would foster playful behaviors.

5.3. Shaping the future of pervasive interactive spaces for animals

Regarding the research question RQC on how do dogs behave when interacting with the system in each modality, Table 3 shows that the observed behavioral patterns were varied among the different dogs, as their reactions to an interactive system are subject to change due to different aspects. For example, individual personalities might affect the amount of playful time the dog spends with the system [2] or the dog behavior and reaction towards different aspects of the technology, e.g. robot's speed, shape, or movements, as has been observed with other species [15] . Other factors affecting the interaction could be the novelty of the environment, the dog's mood, and the presence of other dogs or humans. These observed differences in the behaviors motivate the creation of adaptive pervasive systems that learn not only from the animal's movements but also from the contextual information that could affect the interactivity levels of the experience. In this regard, the data input from the remote interactive game with humans could shed some light on which features the system should consider, as this interactive modality usually resulted in more engaging experiences for the animal. Whether this is just the movement of the dog or more fine grained considerations, such as its body posture as proposed in previous works by the authors [71], deep learning techniques could help identify which movements or interactions seem more relevant for the animal.

The six dogs showing playful behavioral patterns enjoyed the activity and showed willingness to go on playing when they were outside the playful area. Some of these demonstrations of interest included following the researcher during the setting up of the installation, entering the play area and walk straight to the robot whenever the door was open, and waiting outside the play area constantly looking at the robot, even trying to reach it with their paws. In parallel, there were also some dogs that showed interest in the robotic device but perhaps the interaction did not last long enough for them, or the set-up was not suitable for them to start playing. As shown in Table 3, the majority of the dogs displayed a passive or an alert behavior at least once during the session. Of the twelve dogs displaying a passive behavior, five of them showed an alert behavior at some point during the session, and only four dogs eventually reached a playful or intense playful behavior. This shows potential for deploying this kind of pervasive environments for a longer period of time, which would allow shy dogs to acclimatize to the new elements in their surroundings, and could eventually lead to their wanting to participate in the interactive experience. In addition, a permanent installation of this type would give more control to the animals in terms of when and whether they would like to play. This could also help to improve the children's experience during a remote interactive game: the dogs would be more active and could give children a more rewarding experience if they see that the animal is enjoying with them.

6. Conclusion and Future Work

This work has presented two main technological contributions, (1) a remote mobile interactive system for humans and animals which allows hospitalized children to remotely control a robot to play with a dog in a dog daycare facility, and (2) a pervasive interactive system capable of playing autonomously with a dog. The main aims of the playful interspecies system described here were to (1) help improve the children's wellbeing during their hospitalization, (2) foster a healthy relationship between children and animals by means of play, and (3) provide physical and mental stimulation for animals at home, in shelters or in daycare facilities.

The remote mobile system allowed hospitalized children who cannot receive the visits from therapy animals to interact with an animal in real time. This system was well received by both children and parents, and presented minimal interaction issues that could be easily resolved to make the interaction more fluid. The children were eager to propose additional features for the game such as having access to different technological devices to play with the robot, or being able to observe other dogs with additional cameras. In order to assess the potential positive impact on the children's condition, e.g. stress or anxiety, a long-term comparative study with a control group that has no access to the mobile application could be conducted.

The results of the postquestionnaires showed positive levels of awareness and empathy towards the animals. The children were capable of identifying the benefits of these playful interactions for the dogs, as well as identifying which dogs were not very interested in the game and asking how they could engage the dog in the activity. This opens the door to the design of engaging educational activities aimed at fostering healthy relationships between humans and animals and to stimulate children's critical thinking and empathy. While in this study the duration of the sessions with children was 10-15 minutes, longer sessions would allow participants to become more familiar with the system and are the main goal for future iterations of the study. Longer sessions will be more suitable when the infrastructure in the daycare facility allows for long-term evaluations, meaning that children could connect to the system whenever they want and play with any dogs that respond to the interactions at that moment within the whole daycare facility. In this way, we could also assess the impact of novelty and familiarity factors in the playful experience of both children and animals.

Finally, a comparison between the child-controlled robot system and a pervasive system that autonomously plays with the dog showed that intelligent playful environments for animals need to learn from human interactions with the species in order to achieve the same levels of interest and engagement from the animal. The long-term deployment of these pervasive environments would verify whether dogs interact more as their confidence and familiarity with the system increases. These longitudinal studies will contribute to evaluate whether these interventions help to reduce animals' stress in the long-term, for what additional physiological data such as measuring cortisol, heart rate or activity levels might give useful information.

Overall, this paper has allowed to identify the next steps to be carried out for the development of intelligent playful environments for animals that give them engaging and adaptive experiences, helping to advance research within the ACI field.

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Postquestionnaire	Code
How much did you enjoy playing with the animal?	Q1
Would you like to play with the animal again?	Q2
Would you like to play this game with other children?	Q3
Do you think the animal enjoyed playing the game with you?	Q4
Do you think playing this game is good for the animal?	Q5
Would you like to know more about the animal?	Q6
Would you have liked to have more animals playing together?	Q7
How much do you like this animal?	Q8
Do you think it is friendly?	Q9
Do you think it is intelligent?	Q10
How easy was it to control the robot?	Q11
What would you change in the game to enjoy it more?	Q12

Table 1. Postquestionnaire 5-point Likert questions and open answer question.

	Q1	Q2	Q3	Q4	Q5	.Q6	Q7	Q8	Q9	Q10	Q11
Mode	5	4	5	[illegible]	5	5	5	5	5	5	4
Mean	4.24	4.05	3.67	[illegible].57	4.19	4.38	4.48	4.48	4.48	3.95	3.33
σ	0.77	1.[illegible]6	1.43	1.29	0.81	1.02	0.98	1.08	1.03	1.40	1.39
Binomial test (p-value)	0.007	0.001	0.38[illegible]	1.00	0.027	0.001	0.000	0.000	0.001	0.78	1.00

Table 2. Mode, mean, standard deviation and binomial test p-value of children's postquestionnaire.

Behavioral pattern	Dachshund, 1y		Mixed-breed (medium-sized), 6y		Beagle 3y		Maltese 4y		Mixed-breed (small-sized), 2y		Mixed-breed (small-sized), 1.5y		Mixed-breed (medium-sized), 1y	
	R	P	R	P	R	P	R	P	R	P	R	P	R	P
Intense play													2	4
Playful	2	6					1		5				2	
Alert	1	6		1	1	2	2	3	5	1		2	2	3
passive			1	2	1	1	2	2			1	2		1

Behavioral pattern	Setter, 3y		Maltese, 4y		Yorkshire, 4y		Beagle, 2.5y		Mixed-breed (medium-sized), 3y		Mixed-breed (medium-sized), 2y		Mixed-breed (medium-sized), 1y	
	R	P	R	P	R	P	R	P	R	P	R	P	R	P
Intense play														
Playful									1	2		2		
Alert							1		2			1	1	1
Passive	1	1	1	1	1	1	1	1		2	1	2	1	

Table 3. Observed behavioral patterns by participant in both the remote (R) and pervasive (P) modalities described as the number of times each dog showed a specific behavior during each session.

Figure 1. System deployment and set-up.

Figure 2. Hospitalized child controlling a Sphero® to play remotely with a dog in a daycare facility.

Figure 3. Communication between applications.

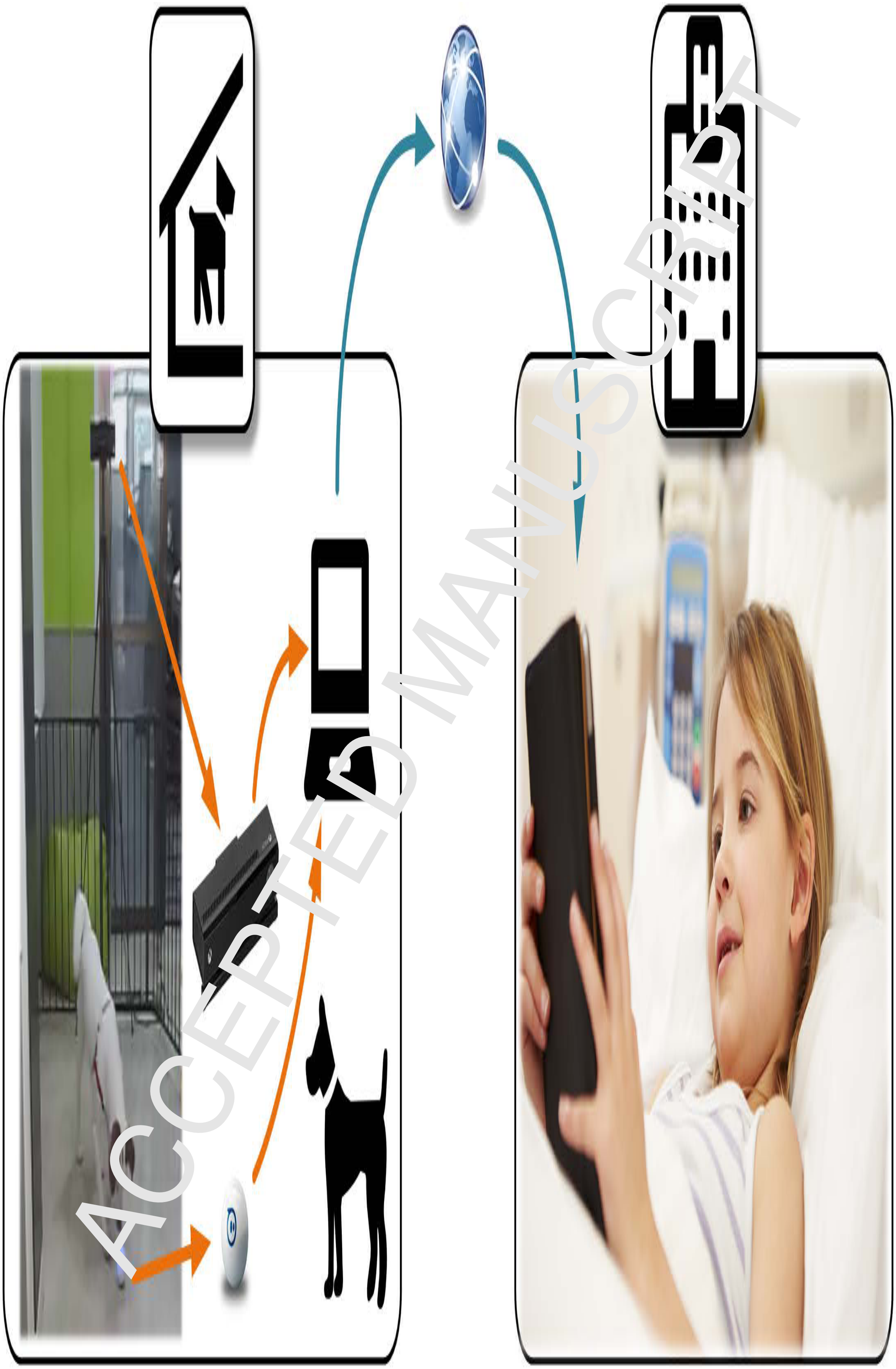
Figure 4. Example of the 5-point Likert scale answer options adapted from Read et al. [63].

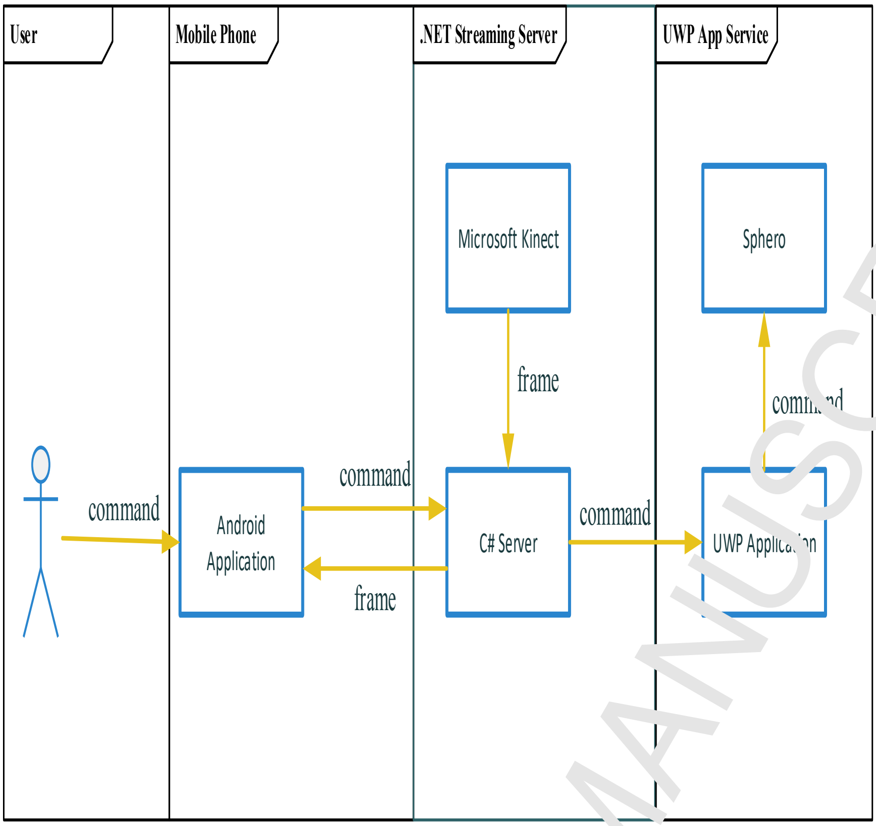
Figure 5. Postquestionnaire results from the Likert scale questions.

Figure 6. Play area for the study.

Figure 4. a) Color stream; b) Detection of dog and robot contours based on movement.

Figure 5. a) Dog interacting with robot; b) Dog not paying attention to the robot.




User
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UWP App Service
Microsoft Kinect
Sphero
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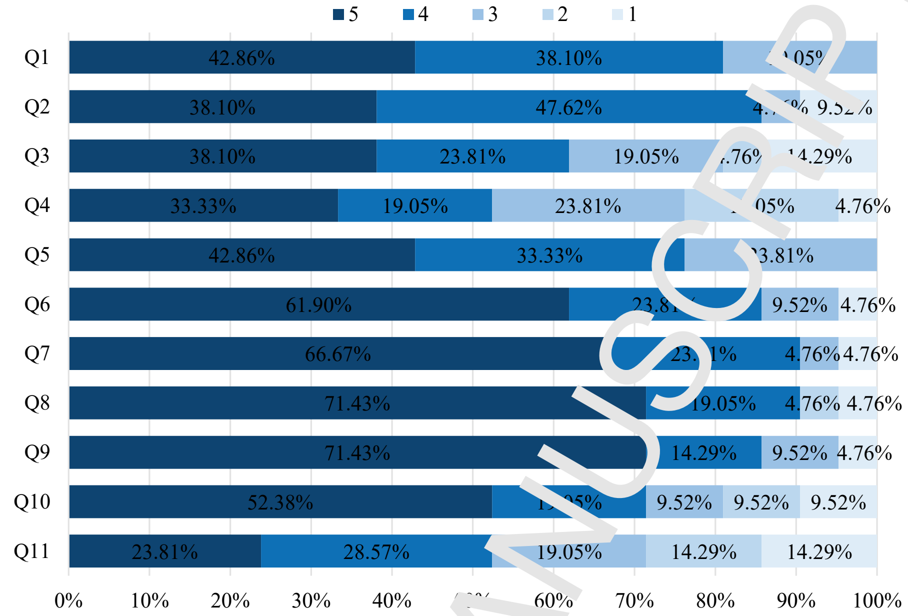
Bad / Nothing
Not great / A little
Good / Neither much nor little
Very good / Quite
Gr / A lo


■ 5 ■ 4 ■ 3 ■ 2 ■ 1
Q1
42.86%
38.10%
19.05%
Q2
38.10%
47.62%
4.76%
9.52%
Q3
38.10%
23.81%
19.05%
4.76%
14.29%
Q4
33.33%
19.05%
23.81%
19.05%
4.76%
Q5
42.86%
33.33%
23.81%
Q6
61.90%
23.81%
9.52%
4.76%
Q7
66.67%
23.81%
4.76%
4.76%
Q8
71.43%
19.05%
4.76%
4.76%
Q9
71.43%
14.29%
9.52%
4.76%
Q10
52.38%
19.05%
9.52%
9.52%
9.52%
Q11
23.81%
28.57%
19.05%
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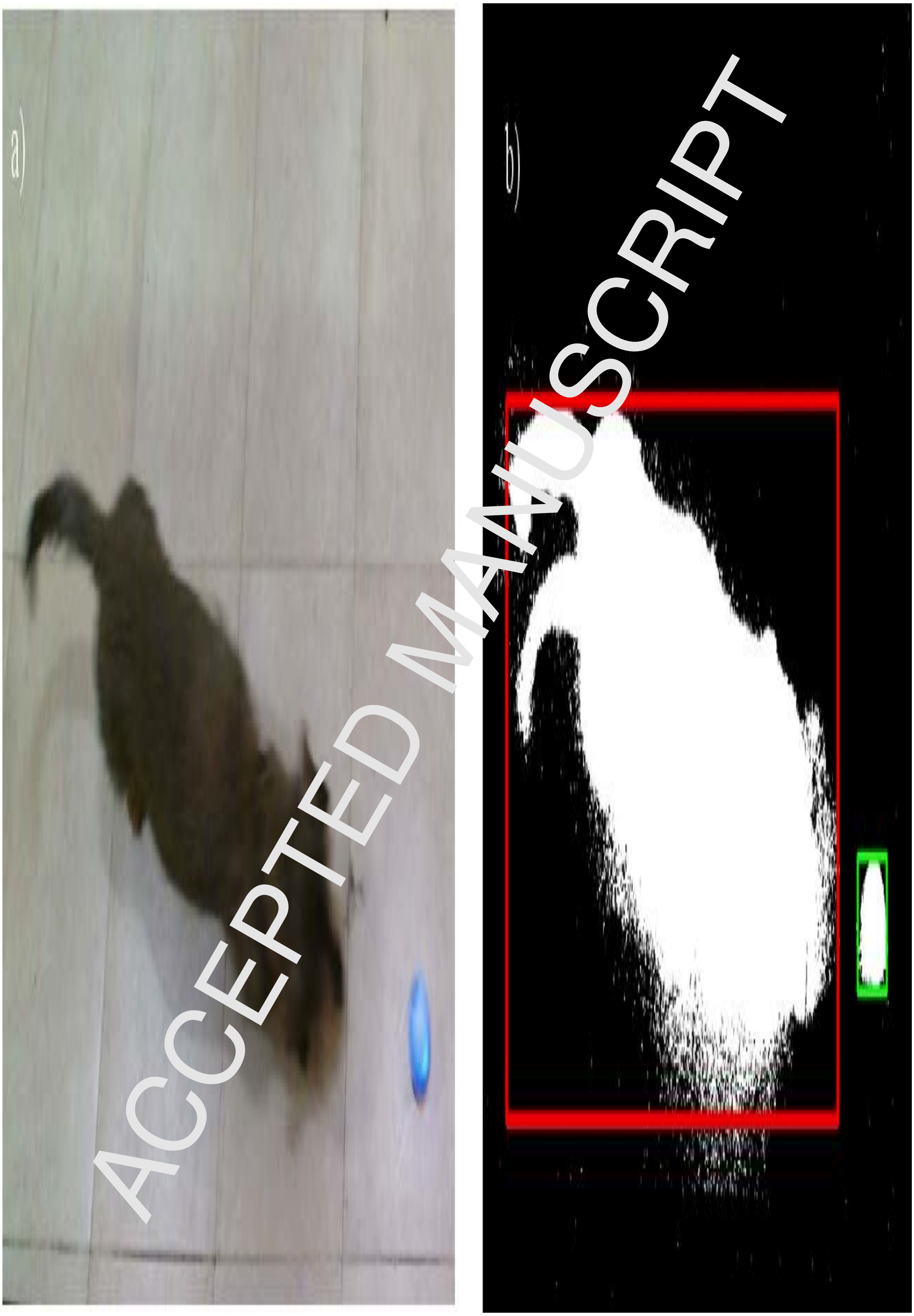
a)
b)


a)
b)