Forming the Dog Internet: Prototyping a Dog-to-Human Video Call Device

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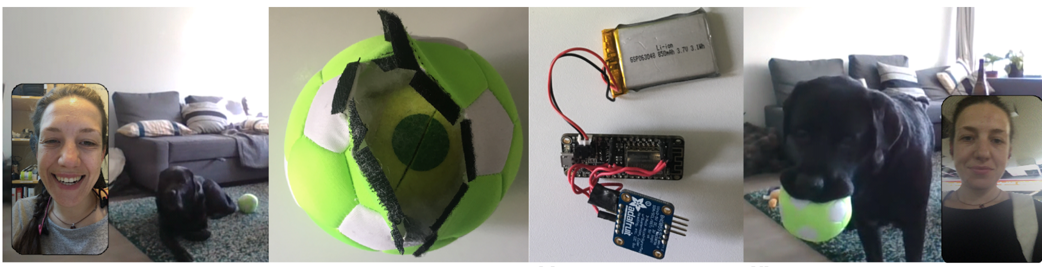

[a] [b] [c] [d]

Fig. 1. [a, d] Screenshots of the video call made by the dog to their human using the *DogPhone* final prototype, [b] final *DogPhone* prototype opened, [c] the hardware housed inside *DogPhone*.

Over the past decade, many systems have been developed for humans to remotely connect to their pets at home. Yet little attention has been paid to how animals can control such systems and what the implications are of animals using internet systems. This paper explores the creation of a video call device to allow a dog to remotely call their human, giving the animal control and agency over technology in their home. After building and prototyping a novel interaction method over several weeks and iterations, we test our system with a dog and a human. Analysing our experience and data, we reflect on power relations, how to quantify an animal's user experience and what interactive internet systems look like with animal users. This paper builds upon Human-Computer Interaction methods for unconventional users, uncovering key questions that advance the creation of animal-to-human interfaces and animal internet devices.

CCS Concepts: • **Human-centered computing** → **Human computer interaction (HCI)**; **Interaction design**.

Additional Key Words and Phrases: animal-computer interaction, participatory design, remote human-animal systems

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1 INTRODUCTION

Like humans, animals have been using computer technology for some time [19]. Akin to HCI, the field of animal–computer interaction (ACI) has started to reflect on an animal's user experience with using, or being involved in some capacity, with technology [18]. Utilising HCI and animal science methods [52], ACI studies how computers can improve an animal's life and how various species of animals can interact with technologies as users across various contexts [13, 15, 19]. From these different methods and perspectives, animals as technology users frequently hold multiple roles within these systems throughout the various product stages [29]. Dogs, in particular, play numerous roles outside of their existing roles as protagonists within our domestic mesh; they may be used as workers, may be free-roaming or may be seen as a companion species in the home.

As their roles develop, dogs and other companion species have been increasingly using more technology systems in the home to support their life and work [44, 45]. For companion species in particular, this technology diversity and ubiquity has resulted in a fast-growing pet technology industry, which is expected to exceed 20 billion USD by 2025 [41]. The majority of these new technologies—dubbed smart toys—are services and systems developed to entertain dogs and cats and connect people with their companion species while they are away from home (e.g. PupPod[1], PetCube[2], PetChatz [3]). These human-to-dog remote calling systems have become more prominent and popular with the rise of Internet of Things (IoT) devices [41].

During the COVID-19 lockdown, there was an unprecedented growth in people acquiring dogs, with for example 3.2 million new dog owners and 11% of UK households taking on new animals, dubbed 'pandemic puppies' [5]. As people have returned to the workplace, many dogs have begun suffering separation distress as they struggle with being left home alone, leading to problematic behaviour [24] and rising concerns over their welfare [6]. To tackle this, IoT devices with remote connection capabilities are flooding the pet sector as a way for humans to remotely interact with their pets. However, their consequences and effects are unknown.

Regarding domesticated dogs, these remote connection systems include video call software for people to ring and connect to them, monitoring collars and other wearable systems to quantify their behaviours and video monitoring software and GPS systems for people to track them [36, 38]. It is now easier than ever to connect, quantify, and track companion animals remotely, resulting in some dogs becoming native wearers and users of technologies, deeply entangled as key users of rich IoT systems.

This entanglement for dogs takes many forms (e.g. wearers, users, observers) and emerges in several situations (e.g. at home, in the wild, at work) across various contexts (e.g. for work, play, enrichment, connection). Yet, what remains unchanged and unilateral across all dog IoT technologies is that dogs as computer users have little to no agency over the systems that they use [18]. Commercial systems are often used on them, within their homes, without their consent, input, or awareness. As more technologies become available for dogs in the home and more dogs become technology natives and users (in some form or another), it is important to involve them within systems that directly affect their lives. Though, how to facilitate a dog's involvement and how to create IoT devices for dogs is still an open and heavily debated topic [44, 52].

One suggested way to do this is to repurpose current dog toys so that the IoT reveals its functionality through the affordances [45] of being self-discoverable and intuitive [13]. However, understanding how to do this, as well as the impact of this repurposing or enhancement of toys for dog-controlled systems, has not yet been investigated [18].

[1] PupPod https://puppod.com
[2] PetCube https://petcube.com
[3] PetChatz https://petchatz.com

This paper investigates the challenges of building a dog-controlled IoT video call device with a dog as user and an IoT controller. Using this video call device, we explore ways to give dogs control over the technologies that they use in the home. We undertake this through a use case between a dog and their human counterpart to create a prototype coined *DogPhone*. *DogPhone* enables a dog to choose when and where to video call their human. We iteratively refined the *DogPhone* prototype over several weeks, documenting our process towards understanding a dog's requirements and affordances in animal-controlled IoT systems. Through our findings about *DogPhone*, we question what the appearance and function of IoT devices look like for dogs and if we can build and design systems for and with dogs as users.

RQ1: What does it look like for a dog to control a video call device?
RQ2: How can humans prototype an interactive device with and for dogs?

This research is especially timely because of the suddenly and rapidly growing pet technology sector, in which animals must be taken seriously as computer users. Research such as this paper investigates how technologies can support animals to ensure best practices. It is vital to both industry and academic contexts that animals are supported within these systems to prevent systems that negatively affect their welfare unwittingly. This work is beneficial to researchers and designers concerned with two-way communication systems between animals and humans and those who develop animal-technologies as it provides a method to prototype with animals and key questions that reflect on what makes successful future systems.

2 RELATED WORK

Animal–computer interaction (ACI) research explores how animals interact with computing systems and how we can design these systems with animals in mind [19]. ACI systems have been used to measure an animal's experience towards interfaces [1, 2, 13, 15, 23, 54], to develop new methods to measure and quantify an animal's use of computers [8, 20] and to generate theories regarding how we can scope an animal's interactions with computers [12, 53]. ACI research covers a multitude of animal users in various situations: e.g. non-domesticated animals in enclosures, such as elephants, parrots and apes [13, 16, 17, 54]; farm animals, such as chickens [30]; wild animals, such as deer [27]; and companion animals, such as dogs and cats [23, 44, 45, 53]. Unifying these various end-users and usage contexts are the underlying methodologies and theories of designing interactive systems for the different cognitive abilities of animal users.

2.1 Animals as Users of Interactive Systems

Dogs arguably hold the most diverse roles and positions with computer-enabled systems due to being present in home, wild and work contexts [44]. These vary from being entertained through screen systems [23], working by pressing buttons and pulling ropes to notify people [8, 12, 45] and informing people of their experiences through the use of computer systems [32, 44]. Dogs as actors can be technology consumers [11], users through button pressing and activating screen systems [23, 44, 56], users as wearers of GPS technologies through GPS trackers and vest monitoring systems [8, 34] and game players through gamified tablets [53].

Looking at a dog's position within technology systems, they often hold multiple roles, which can be dissected in different ways depending on the designer's vantage. One popular dichotomy made by Lawson et al. [29] is the appropriation of Baumer's [4] term *usees*, where animals are imposed into using systems unknowingly. This is contradictory to the standard definition of *users*, where animals are seen as directly controlling systems [39]. As this dissection implies, an animal's role has implications on their agency in computer systems. For human–animal remote communication systems, dogs are *usees* as humans connect with them without their consent as they respond to either verbal cues and/or food [46]. However, the extent to which a dog can understand remote technologies and their perception of them remains unknown [50].

In research, dogs take on different roles throughout the various product development stages, but mainly in the later phases of testing and implementation. Dogs are often involved indirectly through their human counterpart through a user-centric approach [44]. Here, humans act as an advocate for the dog (their caretaker or welfare specialist) due to the lack of linguistic abilities and differences in cognitive factors that impact typical methods of measuring feedback and quantifying the user experience [21, 32]. It is debatable, though, how much input a dog actually has within this role, as the dog's voice is mediated through human understanding, translation and acknowledgement [9]. Furthermore, in dog–human internet connected systems, human needs are considered over an animal's—if the animal's needs are considered at all [50].

Hirskyj-Douglas and colleagues [19, 21] state that computer-enabled systems used by dogs are traditionally motivated, conceived and developed with human purposes, orientations and goals. Looking at dogs' roles within current technologies, when dogs use computers, humans have decided to make dogs wear the technology [34], to train dogs to use technologies so that we can use their senses to inform us [25, 32], to collect physiological information from the dog unknowingly [23] or to train the dog to respond to us through technology-mediated systems [45, 47, 51].

Noting this, Torjussen et al. [50] encourage the exploration of how dogs understand remote human–animal technologies and their perceptions of such technologies as they seek for animals to have more control. Likewise, there have been design fiction speculations made regarding how dogs can control dog-to-dog internet systems [18]. However, aside from these speculations, there is a knowledge gap regarding how dogs can control these remote video call systems with their needs and requirements being considered (RQ1).

2.2 Prototyping with Animals for Empowerment

Researchers, noting that dogs have little agency in technologies, have recently begun to look into how dogs can control technology to initiate their own interactions when and wherever they choose. [22]. As part of this emerging research, there has also been an increase in methods that involve dogs within the design process as a way to give them more agency, consent and influence over the systems they use [18, 44]. This research trend is part of a larger shift in ACI, of moving towards co-design and participatory practices across multiple species (i.e. with dogs [18, 45] and orangutans [52]).

Animals having empowerment to use technology has been long advocated for [31]; however, it is tricky to define what empowerment is, or what it looks like, within the scope of animal–computer systems because animals cannot provide typical feedback (written or verbal) to measure user experience and understanding. One way empowerment for animals can be seen is as a further delineation of animal rights with technologies. Here, many researchers argue that animals are entitled to their existence and basic interests, including the right to be treated as individuals with desires and needs, rather than as property within computer systems [9, 28]. Building on this, there have been various approaches to facilitating this empowerment with and for dogs.

Väätäja [51] has advocated for empowerment within animal research using the framework of 3Rs; *replacement*, *reduction* and *refinement*. Whilst this framework is typically used in medical science for animal testing, Väätäja orients this towards computer research. Building upon this, Mancini and Lehtonen [32] have promoted user-centric notions regarding equality in a dog's role in computer systems. More recently, Chisik and Mancini [9] have further argued that participatory design can be used as a lens for more inclusive animal technologies through more methods and a deeper reflective practice. Though, beyond establishing a common dialogue, it is not clear how this would transform, how the human notion of participatory design would apply or what implications of a new perspective for animals on the final computer systems outcome would be. Hirskyj-Douglas and Read [21, 23] have developed three classifications for dog-centric devices depending upon the system's goals regarding animal empowerment; *humanistic*, *a dog's*, or the middle ground of *a joint approach*. In this work, Hirskyj-Douglas and Read [21, 23] argue that, by undertaking a dog-centric design to empower the dog (the *dog's* focus) and facilitating the dog's autonomy, consent and choice, the outcomes of the dog's interactions are different from those generated by the *humanistic* approach. Yet this approach uses drastic definitions and makes generalisations regarding the dog's and human's role; it is not always clear and definable whether the system has multiple goals and stakeholders as in the context of dog–human video systems.

Building on this by drawing upon French et al.'s work with elephants [14] and Piitulainen and Hirskyj-Douglas' [40] work with monkeys, Robinson and Torjussen [44] see empowerment as allowing the dog further autonomy by prototyping various button interfaces as a way for the dog to give feedback on user experience and make aesthetic choices. Noting this, Cox et al. [10] applied the same method of low-fidelity testing and prototyping through evaluating a dog's everyday interaction style and behavioural patterns with a spinning bottle. Analysing the dog's interactions, they make suggestions on how to optimise a dog's gaming experience through different modalities and suggestions for interactive future game systems for dogs [10]. Nevertheless, the approach and implications of empowering a dog through prototyping and low fidelity testing have yet to be explored into fruition (RQ2).

3 PARTICIPANTS

When forming technologies with animals, a close personal relationship with the entity that you are designing for allows for a deeper symbiotic attachment from the understanding drawn from the relationship [32]. This relationship allows for multisensorial language to communicate across species boundaries [7], seeing animals as experts of their own experiences [52] in order to facilitate an interchange [54]. For our study, the participants in this study are the human (the first author) and the dog (Zack) that cohabits with them and their partner. The dog is a nine-year-old black male Labrador who has cohabitated with his human (woman, 30 years old) since eight weeks of age. He currently lives with both his human and their partner (man, 32 years old) in a 70 m^2 apartment. Both humans worked full-time outside the home during the study, resulting in the dog being left alone for long periods of time (Monday–Friday averaging seven hours a day). There are no other animals in the home, and both the dog and humans have full autonomy over the house. The dog and his human have been building and exploring dog-computer systems for the last decade together, having previous technology experience with screen devices and motion and facial trackers, but not with tangible devices.

4 PROTOTYPING *DOGPHONE*

We built a dog-activated video call device, with and for a dog, named *DogPhone* to explore our two research questions: how can a dog interact and control video call devices (RQ1) and what are the ways of prototyping interactive systems for dogs (RQ2)? This device allows a dog to video call their human through an object interface. To inform the design of this system through prototyping, we first look at how the dog interacts with items in their environment, test various forms and aesthetics to build a device for the dog and then develop the software and hardware for the *DogPhone* prototype from these results. The following section narrates this process.

We chose a video interface concept for this work because this is the most popular system used by humans to remotely connect to their dogs [41] and almost 50 percent of dogs studied have shown interest in visual screens [23]. The video interface also provides one way to give dogs control of when to trigger and use technologies that are native in their home environment (TV, tablet, computer and phone screens). Dogs have been shown to be able to recognise their human caregivers over strangers [26] and discriminate human emotional facial expressions on screens [35]. Further, dogs have also been indicated to be sensitive to social affective human-dog interactions, differentiate between social and nonsocial interactions [26] and are affected by humans' behaviour inferred from screens when making decisions [33]. As such, it seems reasonable to argue that dogs recognise their human and can infer social information on screens. While these visual and auditory interface decisions are not traditionally oriented towards a dog's primary sense (olfactory), this decision was based on the availability of technology and the ease of creating and deploying reliable prototypes.

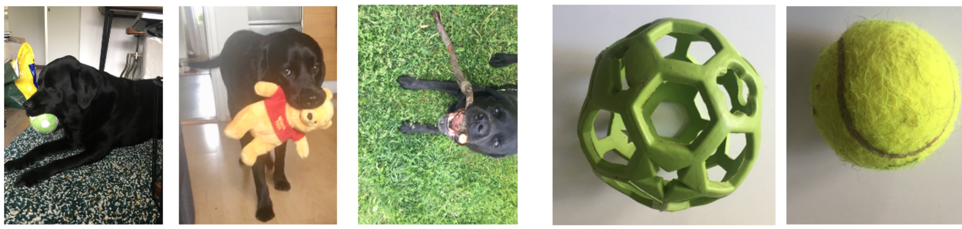
In forming *DogPhone*, we used the established ACI approach of not training the animal (beyond the demonstrations) to use the interface typically used in the context of enrichment, play or technologies aiming towards giving the animal control [19]. This animal-centric design perspective is viewed as an approach to allow the animal to explore the technology in their own way [55] where no interaction is wrong, allowing for re-designs based on observed interactions in a research through design fashion [13, 14, 21].

4.1 Forming the Shape of the Interface

When designing and building *DogPhone* as a system, it was important that we consider how to map the affordances of the device towards the dog end-user and to build feedback methods that meet the dog's requirements. Building upon prior guidance [10, 40, 45, 55] for prototyping with animals, we iterated technical and non-technical prototypes with the dog, shaping the system through the dog's everyday interactions with objects. We use everyday interactions to build systems centred around a dog's affordances with tangible objects to encourage the usability of systems. Our research began by seeing how the dog (as our primary stakeholder) interacts with everyday objects and with their human. In this way, we aimed for systems that allow for a dog's computer interactions with their human to resemble normal dog–human interactions (or more generally, animal–human interactions).

We began this process by noting what toys the dog frequently used to interact in meaningful ways with their human and the world. For our dog participant, these were naturally occurring items (such as sticks, grass, flowers and leaves) and toys (such as stuffed toys, balls and ropes) that the human provided or that the dog found outside the home. Interacting with these objects, the dog often used their mouth to bite, shake and carry the item, as well as used their paws to re-position or hold an item still whilst chewing, licking, grooming or sniffing. Between the dog and human, these items (natural and human-provided) were often used as mediators and signals for their play becoming a form of communication.

Looking at how technologies could be integrated into objects to trigger the interaction, prior intuitive interfaces have included buttons [15, 44] and dogs toys (such as ropes) as interfaces [45] and boundary-boxes as non-physical interfaces [22]. For our use case, we excluded buttons because these interaction mechanisms did not ordinarily occur within either the human's or the dog's own environment, and the dog did not know how to use these interfaces. For boundary-boxes, our dog participant had prior experience with this technology but did not prefer to interact in this manner, so this method was excluded. Touch interfaces in turn require extensive training, going against our method [8, 56]. Likewise, we excluded gaze/head direction, as dogs typically look at screens for under three seconds at any one time, having an overall low mean attention time [22, 23]. These factors make these methods unsuitable for activating screens in our use case. Thus, informed by the knowledge of dog–human relationships and the literature, we chose the method formed by Robinson et al. [45], using a dog toy as an interface. Furthermore, using tangibles as an interface for computers have recently been recommended to fit with an animal's affordances being intuitive



(a) Dog Ball (b) Stuffed Toy (c) Wooden Stick (d) Hollow Ball (e) Tennis Ball

Fig. 2. Items given to the dog to test as interfaces

[52, 55]. Prior work additionally provides evidence that using already known objects allows for constant affordances [8, 18, 30] and reduces usability training [32].

To explore what toy to use as an interface and its functionality, we gave the dog new versions of his most preferred items to interact with his human in their everyday environment. Aligning with animal-computing methods of observing animals as experts of their experiences [14, 52], the human catalogued these interactions over one week. The human did not encourage the dog to use the items but would play with the dog and the item if the dog initiated this play style (such as throwing and holding the item). As the dog had constant access to the items over a long period, we did not video record or quantify these interactions. Future work would benefit from recording the dogs' interactions with objects for post-analysis; especially the initial interactions where most of the interest is held and exploratory behaviours displayed.

The items given to the dog were *a soft ball*, *a stuffed toy* and *a stick* (Figure 2 a–c). These items were the size that the dog had previously chosen to play with.

When the dog interacted with the *stick*, he mostly chewed the ends of the stick into smaller pieces and ran with the stick, bashing it around. The stick had dry leaves that he could shake and rustle to provide a multisensory experience. However, due to this behaviour, the stick eventually wore out over a few days and was largely abandoned after the initial exploration and fetch games.

Regarding the *stuffed toy*, the dog would carry this around the house, often greeting humans (both human friends and those he lived with) entering the house with this item. The toy also had a dual purpose—the dog would groom, lick and chew the toy whilst he was relaxing and solo-playing. With the *ball*, the dog would carry this around the house, often holding it in his mouth. However, he did not engage in licking/grooming behaviours. The dog only engaged in chasing behaviours with these objects (*ball*, *toy* and *stick*) if they were thrown by a human. Besides chewing, this was the secondary purpose of the stick. The dog mostly preferred to carry and play with these objects around the house.

From this form exploration, we decided to use a *ball* as an interface as the dog did not engage in other behaviours, such as chewing and licking, with this form. Additionally, this form factor was frequently used as a mediator for human–animal relationship regarding greeting and playing interactions. Thus, this formation already had prior meaning and usage for the dog–human relationship to build upon.

4.2 Aesthetics

After deciding upon the ball form, we tested other ball interfaces to get the dog's input on aesthetic properties such as texture and material. This has recently been noted as a key factor in animal interfaces [14, 44]. To test aesthetic factors, we gave the dog an additional *soft plastic hollow frame ball* and a *tennis ball* (Figure 2d & e) to play with over a week, each representing different textures, weights and levels of solidity. As prior, we used the dog's humans to judge their engagement and experience.

Over the week, the dog did not interact with the plastic frame ball and, after an initial investigation, through sniffing, licking and chewing, he ignored this toy altogether. Regarding the tennis ball, the dog associated this strongly with playing fetch and would repeatedly fetch this ball, dropping it and throwing it towards any human within the home/outside to initiate the fetch play style.

From this exploration, we found that the dog participant mostly chooses to play with soft forms that have a uniform structure and keep their shape reasonably well. Thus, our final form was the original tested *soft ball* due to it being the dog's preference in terms of frequency of usage, the behavioural affordances seen by their human, its mediation factor between the dog and human and its lack of prior behavioural associations.

Drawing on these insights, in order to signal new affordances (such as interactive features), we got a new ball interface for *DogPhone*, similar in size and material to the dog's preferred form (Figure 1b). To create space for the technology, we placed a tennis ball within the middle of the ball to protect the dog from the technology components whilst still allowing the ball to maintain its squishy form factor.

4.3 Interaction Technique

With the ball form chosen, this toy had to be made into an IoT video call system where technology was enclosed within the device to detect interactions and enable the *DogPhone* functionality. As it is currently unknown how much a dog can understand their interactions with computers [18], it is generally believed that animals exist somewhere on a continuum of understanding [37]. To allow for this continuum, many in ACI build methods that require simple behaviours for interacting, such as pulling [12, 45], entering a zone [23] or touching an interface [14]. Since the dog moved the ball when interacting with it, and especially when interacting with their human, we chose movement as the main interactive mechanism and mapped this to the core functionality of the system. Though, this carrying behaviour is often a breed-specific trait to Labrador dogs, where other dog-human relationships would need to explore interaction techniques that fit their relationship and interaction style.

For the dog to call the human, he would have to move the device in any direction, which would then remotely activate the video call and display it on a screen placed in the home. The dog would then be informed that they had triggered the interaction via a telephone ringing sound from the screen device. We chose the screen device to make the noise rather than the ball, as this is also where the visual stimuli would occur. The human user could then answer via their phone to initiate the video call, which would take place on-screen using a camera placed above the screen.

When thinking about how to end the dog–human interaction, we had several options: the dog participant could drop the toy, a time limit could be set for the dog or the dog could walk away from an interaction space (in front of the screen) to end the interaction. However, drawing on prior work [22, 45], all these behaviours could occur for other reasons; such as the dog getting another toy to show their human, the dog being tired of carrying the toy so dropping it, or perhaps the dog not wanting to be limited by time with their call. Thus, we left it up to the human user to decide when to end the call. Furthermore, as a safeguard, since the dog's human could end the call, we mitigated against negative behaviours that could potentially occur due to *DogPhone*.

With video calls being two-way interactions between entities (here the dog and the human), we additionally needed to allow *humans to call the dog*. This enabled the video to be two-sided (both human- and dog-initiated), allowing for an equal video call procedure. This method mirrored ordinary non-technological interactions, where both humans and dogs initiate interactions with each other. To enable the technology to facilitate these dyadic exchanges, the human participant could also initiate the video call via ringing in a phone app, which would cause the screen device in the home to ring (make the ringing sound). The dog could then choose to answer the video call by moving the *DogPhone* device in any direction.

The above method formed the basic interaction mechanism of starting the *DogPhone* device and facilitated dog-led interactions with the device. While this is a nonspecific interaction method (moving the ball in any direction), this interaction style also allowed for the constant affordances of the toy initiating the video interaction, assigning a clear linear meaning to the toy and the video call [56]. As it is unknown how dogs experience, are motivated by, or can control interfaces—this work begins to take steps and discuss how dogs understand, are motivated intrinsically to use and what benefits they get from remote video call systems.

4.4 Hardware and Software

Our *DogPhone* hardware prototype consisted of an Adafruit Feather Huzzah ESP8266 board and an Adafruit BNO055 Orientation Sensor (Figure 1c) placed within the ball. The Orientation Sensor combines accelerometer, magnetometer and gyroscope data to output device orientation in three axes. Detected movement was wirelessly broadcast to a nearby laptop using the board as a WebSocket server. This sever broadcasts a signal to connected clients when a movement was detected, i.e. when the sensor readings were changing for a number of timesteps and the current ball state was non-movement. We decided upon these timesteps after testing the device inside the tennis ball to remove false positives. Here, we found that, due to the sensor not being stationary inside the ball, it was prone to micro-movements; thus, it needed to be less sensitive. The laptop used for the video call ran a Python script that would connect to the WebSocket server (i.e. the ball), listen for the events that it broadcast and start a call when an event-signalling movement was received. Via the computer, the device then logged the timing and duration of the call or whether the call was unanswered. The ball could be charged via attaching a USB wire through the tennis ball opening, with LEDs on the board indicating its charging state. When the ball was not charging and with the dog, the ball remained fully enclosed with the technology shielded by the two ball layers. While this system worked for our dog as a user, as he does not chew the interface, other dogs will need to test this form factor. The laptop that the *DogPhone* ball controlled was an HP 14" notebook. The screen was placed at the dog's head height with the sound at 50% volume, as recommended by previous dog screen research in the home's living room [22]. This allowed two-way video and sound communication. To enable us as researchers to check on the system's settings and status of the *DogPhone*, we also used remote viewing and control software.

The software, schematics and installation guide to build the device can be found on GitHub [4]. The total cost of the components for the device is approximately 30 GBP making this a relatively low-cost system.

5 METHOD

To measure the dog's and human's use of *DogPhone*, we employed the established HCI mixed-method approach of combining a diary study and advocated interpretations from the human side, with quantitative interaction data from the dog's interactions with *DogPhone* itself. Such approaches have previously been employed in animal-technology as a way of facilitating animals' feedback as experts of their own experiences [52] and to support reflection on the interaction [3, 44, 53]. These methods also work with dogs in their own home and enable the collection of insightful data whilst also giving dogs control and agency over the interface [22].

[4]GitHub for *DogPhone* https://version.aalto.fi/gitlab/piitulr1/dogphone/

To record the *DogPhone* interactions, the software logged the time and timing of the video call, as described previously. The human wrote down what happened in the call and why they ended it in a diary, and also took screenshots during the call. To analyse the data, the quantitative data was paired with the qualitative diary data and corresponding screenshot.

To introduce our dog participant to *DogPhone* and the interaction mechanism, the other human (partner) living in the home demonstrated to the dog how the ball could be used to call the dog's human. A number of studies with adult dogs have shown that dogs can learn and obtain different types of social skills through observation and learning from humans in various contexts [42]. This demonstration was done five times. Both human and dog initiated calls, with the human's partner simulating the answering mechanism. These calls were between 19 to 146 seconds long and included the two humans talking to each other and the human partner giving the dog the ball to interact with and initiate a call. During this training phase, the human in the home (partner) noticed that the dog often seemed confused and excited; the dog would often look around the back of the screen and look towards the laptop. In the diary, the human wrote "*didn't really touch the ball, then got super excited over the ball*". Regarding the second test call, the notes read: "*finally touched the ball and was happy*" after which he "*then deposited the ball back away into his toy box*". On the third call, it was noted that the dog "*just sat with the ball towards the screen and watched the screen*".

6 RESULTS

The dog was left home alone for an extended period (averaging eight hours per study day) of sixteen study days over a three month period; days 1–2 marked iteration one, days 3– 9 marked iteration two and days 10–16 marked iteration three. The sixteen days were not consecutive, occurring only when the dog was left alone during the working week (Monday to Friday). As creating this phone was a process of mitigating between the dog's user interactions and experiences and the device's affordances, the results are presented here over the three iterations of *DogPhone*. The design itself and the building of interactive systems have been described as iterative processes of seeing-moving-seeing, where people see the phenomena and then edit the design before seeing it again [49]. This describes the important iteration below, where we 'see' the dog and our dog–human relationship 'moving' in response. Then, we 'see again' in iterations between us as humans, the dog and the system. It is in this way that we continually shaped the prototype around the dog, the dog–human relationship and their interactions. This results in that the iterations differed in length, and changes were implemented when needed.

6.1 Iteration One: Video Interactions between a Dog and Their Human Using *DogPhone*

The first iteration lasted two study days (Days 1–2, Table 1). In this iteration, the *DogPhone* device would place a call if there were several continuous movements detected. As Table 1 demonstrates, during iteration one there were many calls made by the dog: 18 in total, 9 per day, averaging 1 min 8 seconds. Half of these calls made by the dog (9/18) were when they were asleep with the ball (dreaming) or laying on-top the ball, suggesting that the ball is too sensitive to the dog's movements, with the calls possibly disturbing the dog's resting time. During the calls, the dog would often look at the screen, but would not move or make any sounds. We consider these 'accidental' calls as we did not consider the dog to be awake. In the diary, it was written that: '*there is a real tension here between wanting him to know I am calling and disturbing his day. I don't want him to be too focused around me, and my need to call him*'.

During the longest call, the dog brought their pink pig feeder puzzle toy towards the screen device in a typical behaviour exhibited in-person in the household. The dog then threw their toy

Table 1. Iteration One of *DogPhone*

Day	Time	Duration (s)	Details
1	9.18	58	Dog moved the ball, and when I called showed *DogPhone* looking at the camera wagging. Dog lost interest in the call so hung up.
1	9.20	30	Dog called by accident. Dog was playing with his pig and accidentally nudged the ball.
1	9.48	16	Dog called by accident (climbing onto sofa) and then went to sleep.
1	10.42	179	Dog carrying the toy stretching and walking around, very happy and wagging. Near the end of the video he was whining, so I hung up.
1	11.43	16	Dog was sleeping with the ball and knocked the ball when he was dreaming.
1	12.00	30	Dog asleep on the ball.
1	12.31	66	Dog was lying on the ball semi awake but going towards sleep and nudged the ball. Hung up as he was asleep.
1	13.25	49	Dog was awake and woke up more when I spoke to him (ears perked and looked up towards the camera) but seemed sleepy so I just said hello and let him back to sleep. Looked like I was bothering him.
1	14.43	189	Dog was walking around and then I picked up. Rang me by accident, but he then came to the camera and went and got another toy to show me this, whilst wagging around the room and purring at me. I spoke to him about the dog park we are going to later, asked about his day and complained at the street noise. He then disappeared for 20 seconds while I waited in case he was finding something for me.
1	15.11	32	Dog walking around wagging and then laying down. I was in a meeting so had to hang up quickly.
1	17.02	102	Dog had just woken up and spent a while just staring at me, I was traveling so my signal was weird. Was looking at the camera and walking around, hung up as lost signal.
2	9.29	44	Dog rang me but was not interested in our call instead was checking for things in his bed. He was busy elsewhere.
2	10.24	6	Dog asleep with the ball.
2	11.19	43	Dog asleep with the ball.
2	11.27	40	Dog asleep with the ball.
2	12.21	17	Dog asleep with the ball.
2	13.16	19	Dog asleep with the ball.
2	14.11	15	Dog asleep with the ball.

constantly at the screen in a manner that is typical to get their human to fill the toy pig with food. During this process, the dog was whining. The human interpreted this as typical in their communication, since the dog is typically rather vocal in their exchanges. The human rang the dog once on Day 1, but the dog did not answer, so this was not reported in Table 1. Due to the several 'accidental' calls made by the dog, we concluded that the ball was too sensitive. We stopped phase one after Day 2 to modify the *DogPhone*'s settings to suit the dog's behaviour with the ball.

6.2 Iteration Two: Video Interactions between a Dog and Their Human Using *DogPhone*

In phase two, we changed the *DogPhone's* sensor configuration to require more significant movement, i.e. a greater magnitude over several samples required to trigger a video call. The dog was then given access to the *DogPhone* system for a period of seven days (Table 2; Days 3–9). A total of two calls were made over seven days. On Day 3, we (the human) called the dog, but they did not

Table 2. Iteration Two of *DogPhone*

Day	Time	Duration (s)	Details
3	11.06	35	Dog rang me from his bed with the ball, he must of knocked it or been playing with it, was laying down and not really paying me any attention so I hung up.
3	11.19	18	Dog was sleeping with the ball and dreaming.

pick up. As can be seen in Table 2, the dog did not use *DogPhone* after the morning of the first day of phase two (Day 3). However, we noted that the *DogPhone* would have moved in the home over the period of the day, suggesting that *DogPhone* was not sensitive enough to pick up dog movements. Throughout this period we used our remote software to check that the systems were still running as intended. The software ran fine throughout the study period, so this was not a system issue, but rather a sensitivity issue. During this iteration, we (the dog's human) initially became annoyed that the dog did not want to call. In the diary, it was written "*What if this is just a manifestation of my own desires for his empowerment [in video technology] that he doesn't want?*" The dog's human also began to use the remote log in system to view the dog throughout this period to check on the dog.

6.3 *DogPhone*: Iteration Three

The third and final *DogPhone* iteration was refined so that motion sensitivity levels were between the iteration one and two sensitivity levels. As a result, the device was sensitive enough to allow the dog to sleep with *DogPhone* without triggering a call, but allowed calls to be made with more minor movements when the dog was in contact with the ball. This iteration lasted seven study days.

There were 35 calls made by the dog (averaging five per day; Table 3, Figure 3) and one by the human on Day 15. As previously, the dog did not answer the call, so it is not reported in the data. The dog's triggering of interactions changed daily (Figure 3). Equally, the amount of time the dog and human spent in a video call mirrored the number of interactions triggered by the dog (Figure 3).

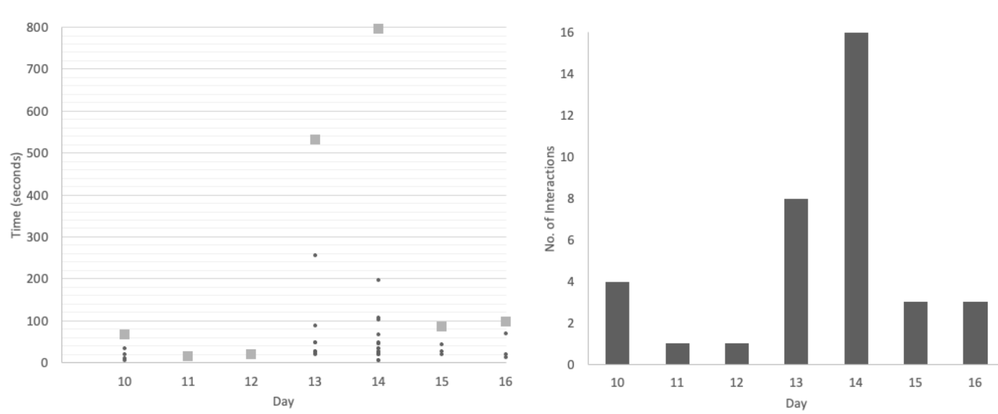


Fig. 3. Iteration Three of *DogPhone*. Left: Use time (in seconds) of calls per day with *DogPhone*. Dots are individual phone call duration and square dots are total duration per day. Right: Number of interactions with *DogPhone* per day.

Almost all (34/35) calls were coded as being made by accident. This is due to the dog not responding to the video call from the human's perspective, but we do not know a dog's thoughts

Table 3. Iteration Three: Video Interactions between a Dog and Their Human Using *DogPhone*

Day	Time	Duration (s)	Details
10	9.15	9	Bad connection, unsure as to what is going on.
10	9.20	33	Dog was sleeping called by accident.
10	9.45	19	Dog was sleeping cuddling the ball.
10	10.03	5	Dog sleeping cuddling the ball.
11	10.16	15	Knocked as he was sleeping.
12	10.57	20	Knocked as he was sleeping.
13	12.47	47	Sleeping but I wanted to see him.
13	15.11	26	Dog sleeping with the ball.
13	17.45	19	Dog sleeping with the ball.
13	18.07	27	Dog sleeping with the ball, woke up for the call.
13	18.11	47	Knocked the ball by accident.
13	18.12	21	Knocked the ball but I spoke to him as he kept on ringing me looking at the camera.
13	18.14	256	Wouldn't stop ringing so I left it on as I was walking around the underground. Liked listening to the flute buskers, approached the screen so I paused to let him listen.
13	18.29	87	Accidentally knocked the ball so I showed him around the underground and the city.
14	9.33	33	Dog sleeping with the ball.
14	10.49	5	Dog sleeping with the ball.
14	12.15	6	Dog sleeping with the ball.
14	16.19	20	Dog sleeping with the ball.
14	16.34	197	Dog sleeping with the ball.
14	16.37	32	Dog sleeping with the ball.
14	16.39	67	Dog kept on ringing so he watched me work.
14	16.50	45	Dog sleeping with the ball.
14	16.54	48	Dog sleeping with the ball.
14	16.56	21	Dog sleeping with the ball.
14	17.12	24	Dog sleeping with the ball.
14	17.26	20	Dog sleeping with the ball.
14	17.29	26	Dog sleeping with the ball.
14	17.30	102	Left the call on as he kept on ringing me.
14	17.32	106	Dog awake but laying on the ball. I showed him buskers again (classical music).
14	17.54	44	Dog awake but laying down, left call on as he kept on ringing me again.
15	9.28	18	Dog knocked the ball on his way to bed (sofa).
15	18.29	42	Rang me and looked confused so I spoke to him.
16	9.42	69	Accidentally rang me but I spoke to him about my day.
16	10.32	18	Rang me but he was in and out of camera running around the house.
16	11.10	11	Accidentally rang me but I spoke to him about the dog park we are going to visit later.

or intentions. Furthermore, the interactions were often triggered through the dog leaning/lying on the ball with their shoulder or butt. The dog consistently triggered the interaction in this manner, resulting in highly interactive periods (e.g. Days 13 and 14; Figure 3). As a result, during this phase, the dog's human often left the video call running to let the dog see their environment rather than, as prior, directly interacting and speaking with the dog in their normal mannerism (Days 13–16). It is during this leaving-on period that the human found that the dog seemed the most interested and engaged, pricking their ears to listen to sounds and walking closer to the screen device to observe.

On Day 13, in the diary, it was written: '*think today things changed as this was no longer about him just ringing to speak to me, but for me to show him things, expanding his environment*'. This can be seen in the longer interactions on Days 13 and 14 (Table 3) and higher frequency of calls triggered by the dog. On these days, the human started to show the dog around the city by flipping their phone camera. The human showed the dog their current environment and happenings in their locality, including live music, the city itself, restaurants, public transport, people around them and their office workplace. The dog has previously been to the office space and regularly takes public transport, but had never seen these other parts of the city, the restaurants or certain people. This shift results in the system that was intended to connect the human and dog instead became more about showing the dog the external environment. In this way, the human became a mediator between the dog and the outside world.

The human using the device also noted that they started to remote login multiple times a day to view the dog through the screen's camera as a passive form of viewing. The dog's human engaged in this behaviour when the dog was not calling them in accordance with their regular calls (for example in Day 15) because they became worried and anxious about where their dog was. On Day 16, the human contacted their partner (who shared the house with them and the dog) to see if they needed to go home to check on the dog, since they could not view them on the laptop camera as usual. Whilst the dog was okay (sleeping in the kitchen outside of the camera's view), throughout the study, the human slowly formed higher levels of anxiety centred around the dog calling and would impulsively view the dog if it did not adhere to its usual daily patterns.

7 DISCUSSION

With more dogs being subjected to remote video technology to connect owners to their companion animals, we designed and built *DogPhone*: an IoT tangible device designed to give dogs control of their video calls and explore what a video call device would look like when built for a dog user. In this paper, we undertook three iterations with the *DogPhone* prototype, where the dog could trigger a video call with their human. While this work is a case study in itself, the findings have use in two main areas: the first regards a dog's control over their remote video interactions with humans (RQ1) and the second explores how humans can build upon prototyping interactive devices for dogs (RQ2). Considering these implications leads us to some recommendations for dog-to-human interactive applications to help frame this work within a larger body of knowledge.

7.1 What Do Computer Mediated Dog–Human Remote Interactions Look Like?

Looking at the dog's usage of the system, similarly to in Hirskyj-Douglas and Read's work [22], the dog had varying level of daily interactions (Table 3) for unknown reasons. Comparing tangible systems that require movement for interaction, to proxemic that use space [22], the dog had averagely five interactions per day compared to 184 in Hirskyj-Douglas and Read [22]. It is impossible to know if the dog learned to use the system intentionally, what association the *DogPhone* had for the dog, or the weight of breed and prior associations. Still, we suspect that movement and demonstrations alone were not simple enough for a dog to establish a causal relationship of action (moving the ball) and response (making a video call). Future work could take a different approach to reinforce the training phase, that of using a professional dog trainer to support the dog to use a novel interface. This approach has proven successful with training working dogs to use assistive technology [8, 12]. Including training with playful computer systems, however, is highly contentious as many argue that this confuses the animal's motivation, reinforces human-like behaviours [14, 19] and mitigates the animals' consent [23, 48]. More research has to be done in this area to explore how humans can support the animal's understanding of a computer system. However, the findings suggest that tangible systems with movement are not as interactive as proxemic systems for dogs.

Arguably, one of the most challenging steps in the interaction design process when working with animals is finding easily understandable triggering mechanisms for animals to interact with computers. This is not straightforward with animals as they cannot verbally, or in written forms, provide feedback on the interaction design process. To facilitate this process, as was done here, many novel systems developed for animals use devices familiar to the dog such as ropes and balls [8, 45]. While we demonstrated the *DogPhone* system in the testing phase to the dog, more work is needed to explore how to further the structuring and scaffolding in order to enable the learning of how to trigger interfaces. This includes looking at how a dog can understand the interaction concepts, the behaviours required and the result of their behaviours towards an interactive system. Part of this question includes exploring how different interfaces can support dogs accessing and controlling screens and the impact of novel systems. Nonetheless, our method provides one way to begin exploring prototyping with and for animals to create usable systems around their needs and requirements in the various stages of design and implementation.

The approach of classifying an animal's interaction through the animal's caretaker is a valid and commonly used approach in ACI and animal behaviour science [19]. Using this method, the human wrote that most of these interactions were seen as accidental (Table 1, Table 2, Table 3). Prior, Friel et al. [12] have classified dogs as frequently making mistakes, and Robinson et al. [44] stated that dogs might often have unsuccessful interactions in their usage of computer systems. These terms used for describing a dog's usage of computer systems are taken and applied to animals from HCI. Still, it is unclear, in our context, what the terms '*accidental*' and '*interaction*' mean for dogs using computer systems. It could be proposed that a human classifying a dog's usage of technology as 'accidental' might be masking the dog's deliberate usage. As humans, our viewpoint on an animal's behaviour with IoT systems is clouded by our human bias, both of what we see as purposeful interactions with intent and what we see and define as interaction and interactive behaviour. Yet, it is possible that we humans might not know what an animal's intentions are, or how they would interact with computer systems intentionally. For example, when the dog triggered the system with their butt (Figure 1a), this could have been deliberate and the dog's unique way of triggering an interaction. As further evidence to support this, if the dog did *not* want to trigger the video, they equally could have avoided starting the interaction, as dogs have been known to do in prior work [22]. As such, while we begin to explore how to define and see interaction, the question still remains open of what a dog would want in a video call system, their preferences and how we can establish this intent. This highlights that we need to expand further what we see and acknowledge as interaction and engagement for animal-controlled IoT systems by testing systems with animals to build the groundwork. Through exploring systems, as we have done with *DogPhone*, by involving the animal user throughout the process, we can begin to develop new terminology and explore different ways that animals can access and control technology beyond the humanistic world and expectations of interaction.

Aside from the interactions, part of our process of creating and refining interactive *DogPhone* prototypes was to explore how such devices can support interactions between humans and animals. As the human noted, such systems can (and did) cause anxieties for both themselves and the dog, although at different times throughout the process. The initial interactions caused slight distress to the dog, shown through them whining (iteration one), whilst the ability to check-up on the dog and their interactions caused the human some anxiety during later periods (iteration three) because more frequent interactions were expected. Additionally, since the dog never answered the human's calls, the human initially saw this as the dog not wanting any interaction or communication with them. From this, we advocate that systems that connect humans to animals, especially when driven by animals, need to be further explored in order to uncover how to manage these interactions to create positive user experiences for both parties.

7.2 Can Humans Prototype Interactive Video Call Devices For and With Dogs?

One of the contributions of this study was its investigation of the design process incorporating dogs, extending methods developed by prior work [9, 32, 44, 53]. Working with animals is challenging as there is a lot that humans do not understand about dogs and computers; communication barriers hinder traditional design methods and inter-species understanding is limited. Part of this study raises questions about how to make a design user-centred and build systems with dogs as stakeholders during the design process. With dogs, as demonstrated here, this process of unravelling the interconnectedness of human and animal requirements, needs and goals becomes near impossible. Thus, unlike Hirskyj-Douglas et al. [20] who focuses on only animal-centric as a requirement for dog-computer systems, part of building and designing user-centred systems for animals is acknowledging the involvement of the animal as a user and the human as a builder, coder, designer and interpreter.

Furthermore, whilst we aimed to empower the dog, it is unclear how empowering the process actually was for the dog, especially since part of being empowered is being able to understand what is happening [43]. If a dog does not understand what is going on or what they are asked to do, it could be argued that a dog, as an individual, could not consent (informed or otherwise) to using a system. It is therefore our duty as researchers to not overstate or presume agency happens when we make space for it as this makes clear assumptions around understanding. We suggest that, as we have done here with the remote monitoring and human ending the calls, researchers make systems with safeguards inbuilt as part of their method.

As narrated in Table 3, the dog's longest calls, and where they were perceived as being the most interested, were when the human was showing the dog something other than themselves. There is no evidence that dogs recognise places through video alone. Yet it could be argued, then, that video calls that involve animals in general should also involve other elements of the surroundings and context to create a more immersive experience. While Hirskyj-Douglas and Lucero [18] called to attention the need for animal-to-animal internet, and here we explore animal-to-human, the study highlights that there is also a potential use case for animal-to-environment IoT systems.

Beyond this specific case study, this paper contributes that dogs should be *users* and not *usees* of IoT systems in the home, and we explored ways to position dogs as active users in control of such systems. As Lawson et al. [29] note, animals have little or no power to resist technological exploitation. Often, the reality in animal-computing systems is that the sharing of power is minimal and arguably superficial, with terminologies like 'co-design' and 'participatory design' borrowed from HCI and romantically labeled for ACI systems. While with *DogPhone* we aimed to involve the dog through prototyping, we acknowledge that power in design is more than recognising influence and maintaining well-being; it is allowing for direct and measurable ways to share power and agency. We provided one way of sharing power by allowing an animal to choose when and where to access technology and building from their usage. Nonetheless, during the design process, we often questioned whether humans (with very different cognitive and biological needs) can really ever design for and with dogs. While we aimed for equity and empowerment in our approach, this does not necessarily lead towards usable designs for dogs.

Regarding the likability of our designs, we found that the dog would regularly seek to interact with the *DogPhone* ball. He would repeatedly grab, sleep with and play with the ball when given the chance. We propose that because of our approach of prototyping and exploring preferences, the dog might have liked the ball as a play toy rather than as an interaction mechanism for a computing system. As Robinson et al. [45] noted in their usage of tug toys for diabetic alert systems, dogs are not always able to separate a toy's prior affordances towards their current affordance for interaction. Reflecting on this and to aid our prototyping practice, we propose that more work is needed to understand how to transform or leverage these everyday devices that dogs like to use (such as sticks, toys and balls) into computerised interaction devices. While it makes sense to us that these devices afford certain interactions and usability features, it could be more difficult for the animal to realise that objects and their affordances are being used for a transformed purpose. The use of a new unfamiliar toy might have held new meaning, where it would be useful to investigate the impact of the known and new objects. It could be possible that for dogs new devices and objects have to be created (akin to keyboards/mice) to facilitate them in accessing computers. Further, although all the toys used were clean, we did not control for smell, taste and pheromones etc, which could in the future inform the iterative process.

Overall, we approached prototyping with a dog from an HCI viewpoint, where we aimed to reduce false positives inputs and picked the system that the dog user most used. However, as a dog is not necessarily aware of the device or how it works, the so–called accidental inputs led to some interesting emergent behaviours. Some behaviours were displayed by the dog and the human users, e.g. sharing the environment during calls to draw the dog into the interaction. Thus, while the prototyping method uncovered the need for a new approach to designing for dogs, it also highlights the need to rethink how we implement IoT systems for animals. By iterating over implementations and exploring computers with animals through prototyping, emerging and unexpected behaviours are produced. This provides essential scaffolding to shape future systems by forcing us to make conscious decisions about held assumptions and what dogs look like when using IoT systems to access the internet.

8 CONCLUSION

An increasing number of systems are emerging that allow animal owners to remotely video-call their companion animals when left home alone for long periods. Yet, animals in our homes have no control over these systems, which are not being designed or built for them as users. In this paper, we design, iteratively prototype and evaluate *DogPhone*; an IoT video call device that facilitates a dog video calling their human when and wherever they choose. Our process gives insight into how to develop IoT systems with dogs by integrating them in the earlier stages of the design process through prototyping and looks at how to facilitate dogs controlling technology themselves. Drawing from this, we raise critical questions around how to manage interactions, quantify what these interactions are, and question how dog devices are formed through prototyping and what they mean for dogs. We hope future IoT remote connection systems will be aided by the early method offered here and by the initial groundwork we have laid for device recommendations both on how to prototype with animals and to open up what dog–human remote interactions look like.

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To my dog Zack, who leaves toys and fur around the house, and joy in my heart.

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