Canine-Centered Interface Design: Supporting the Work of Diabetes Alert Dogs

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ABSTRACT

Many people with Diabetes live with the continuous threat of hypoglycemic attacks and the danger of going into coma. Diabetes Alert Dogs are trained to detect the onset of an attack before the condition of the human handler they are paired with deteriorates, giving them time to take action. We investigated requirements for designing an alarm system allowing dogs to remotely call for help when their human falls unconscious before being able to react to an alert. Through a multispecies ethnographic approach we focus on the requirements for a physical canine user interface, involving dogs, their handlers and specialist dog trainers in the design process. We discuss tensions between the requirements for canine and the human users, argue the need for increased sensitivity towards the needs of individual dogs that goes beyond breed specific physical characteristics, and reflect on how we can move from designing *for* dogs to designing *with* dogs.

Author Keywords

Diabetes Alert Dog; human-animal interaction; animal-computer interaction; user-centered design; multispecies ethnography

ACM Classification Keywords

H.5.2 User Interfaces

INTRODUCTION

It is estimated that, worldwide, 371 million people currently suffer from diabetes, a serious disorder in sugar metabolism [25]. Insulin treatment to manage diabetes can cause sudden drops in blood glucose levels, which are known as hypoglycaemic attacks. Since these attacks can be fatal [31], they are greatly feared by diabetes patients. To try and prevent them, wearable hypoglycaemia alarm machines have been researched and developed which use skin conductance or glucose sensors [2,6]. However, these machines have a certain margin of error and are often not a practical stand-alone solution to manage day to day hypoglycaemic attacks [10].

As a result, Diabetes Alert Dogs (DAD) have increased in popularity over the last two decades. DADs are paired with human diabetes patients and are trained to warn their owners of oncoming hypoglycaemic attacks, giving them time to call for help or take steps to prevent the attack [23]. Diabetic alert dogs use their olfactory capabilities to detect changes in blood sugar in real-time [5,33] and act as an early-warning system for their assisted humans with shorter reaction times and higher precision than existing alarm machines, thus significantly contributing to their owners' quality of life and safety [23]. However, some hypoglycaemic attacks can be so sudden that the owner falls into a coma before being able to react to their dog's alert. If no other humans are around, the dog is then unable to help further, left alone with the unconscious person. But what if technology existed that empowered the dog to take action even in a situation such as this?

Recently there has been an increase in the availability of technological artefacts for companion animals (e.g. programmable pet-food feeders [20], remotely-played interactive pet toys [8,18] location pet tracking devices [29,17,12,28,], and "doggie doorbells" [19]). However, many of these technologies are for leisure or for pet-owner convenience. Indeed, so far there has been very little attention to researching and developing technology that can support the work of animals such as DADs in tasks of critical importance. Therefore we are interested in investigating how computing technology can be designed to assist animal workers in tasks they are already performing. More specifically, our work aims to investigate the development of a system that enables a dog to remotely call for help on their owner's behalf, precisely for those situations in which the owner is unable to act upon their dog's alert.

HCI recognises the importance of user-centred design in order to best support humans in their tasks and daily life. Consistent with this, the growing area of Animal-Computer Interaction (ACI) aims to develop a user-centred approach to the design of technology intended for animals, in order to best support both their welfare and work [13,15]. To this effect, ACI aims to develop frameworks that can account for species-specific characteristics both at the level of usability and user experience, involving animals in the design process as participants and design contributors. However, pursuing user-centred design for non-human users presents unique challenges due - on the one hand - to sensory, ergonomic, cognitive, and cultural differences between canines and humans, and - on the other hand - to the difficulty of relying on verbal communication, so often relied upon by interaction designers. Recently researchers have begun to explore the possibility of adapting HCI research methodologies which combine verbal communication with observational techniques [14,33]. However, this work is yet to be concretely applied in the context of specific interaction design projects for and with animals. Thus here we explore how existing HCI verbal and nonverbal methodologies such as multispecies ethnography and iterative dynamic prototyping, combined with ethologically informed behavioural observation, can be concretely applied to develop specific user-centred interface designs for assisting the work of DADs.

The contribution of this paper is therefore twofold: 1) we acknowledge DADs as a specific user group and explore ways of eliciting their unique requirements and integrating their input in the design process, in order to prototype and evaluate a range of interfaces for a canine alert system; 2) we identify a number of design and methodological implications for the development of user-centred canine interfaces, thus contributing to the development of ACI as a research area.

SCENARIO

Dan has Type 1 diabetes and lives in fear of hypoglycaemia. Like approximately 25% of diabetic patients [3], he has developed 'unawareness' over the years and cannot tell when he is going hypo. Dan's dog, Buddy, is trained to alert hypoglycaemia in Dan by nudging him persistently until Dan acknowledges him and goes to test his blood sugar levels. Many times, Buddy's alerts have prevented Dan from undergoing a full-on hypoglycaemic attack, allowing him to restore his blood sugar with food or drink before it becomes dangerously low. Dan feels lucky to have an alert dog by his side; knowing his dog will alert him has dramatically improved his quality of life.

Scenario A

One day, Dan's partner is out and he is home alone. Buddy smells Dan's blood sugar dropping and gives him an alert by persistently nudging Dan. However, Dan's levels have dropped so quickly that he has already become unaware of his surroundings. Buddy can tell that Dan is going hypo and continues nudging and pawing at him. Buddy even brings Dan his blood testing kit, as he is trained to do when his persistent nudging does not work. However, it is too late: Dan has slipped into a coma. Buddy paces back and forth, distressed that Dan is unresponsive. He knows his owner is in trouble but there is no one else in the house he can alert; he is now powerless at his owner's side.

Scenario B

When Dan, at home alone with Buddy, starts having a hypoglycaemic attack, Buddy knows how to use his special alert system to remotely contact Dan's partner and./or other friends or family, as soon as Dan has become unconscious. Unless Dan is conscious and intentionally stops the alert by typing in an override code, the system is preconfigured to send an SMS to relevant people, who are prompted them to call him and to call emergency services if he doesn't answer. If none of them responds within a set time, the system calls emergency services directly with GPS coordinates of Dan's house. Buddy paces worriedly for a few minutes, but then help arrives. Dan's chances of avoiding brain or heart damage, or even death, have just skyrocketed and Buddy has been spared hours of stress.

What would the part of the system that Buddy uses look like? How would Buddy engage with it? How would his sensorial, ergonomic, cognitive and cultural characteristics, together with the characteristics of the tasks and his working environment, inform the interface design for such a canine alarm? And, critically, how would the researchers developing such a system figure out what kind of interface Buddy might want to do his job? In order to address these questions, we conducted ethnographic research at the UK's leading DAD training center. Working alongside dogs and their trainers, we explores ways of uncovering requirements of such an alarm by involving the dogs themselves in the design process. We took part in training practices to learn how trainers communicate with the dogs; interviewed human-dog partnerships to understand their needs; and engaged in rapid prototyping sessions with the dogs to identify their preferences.

RELATED WORK

Alarm systems

Care home alarm systems and pervasive care monitors [16,27] have been developed to enable vulnerable (e.g. older or less-abled) people to remotely call for help. These systems have been found to provide peace of mind and improve quality of life for those who actively choose to use such systems [1]. Many types of alarm are available, examples including tethered hanging pull-cord alarms, wearable alarms triggered by either intentionally pressing a button, or magnetic quick-release alarms that clip on to clothing and are triggered upon a fall or sudden movement. Although there are anecdotes of dogs being trained to hit an emergency button on a phone, existing alarm systems are not designed for canine use and pose major usability challenges for users with the ergonomic and cognitive characteristics of a dog. This lack of canine usability means that dogs are unable to become proficient in their use and thus cannot be expected to use such systems reliably, particularly at critical times.

Technologies for Working Dogs

However, the development of technology to enhance canine performance in specific tasks is not unprecedented. For example, military researchers have created wearable haptic systems to remotely communicate with and control dogs employed in explosive-sniffing operations. Researchers at Auburn University also developed a similar canine interface allowing a handler to remotely communicate with and maneuver their dog through vibration and sound feedback [4] through impervious terrain during search and rescue operations. Both of these systems place the dog in a reactive position, as though they were part of the operational apparatus, rather than allowing them to proactively use the technology to carry out a task or communicate with their human partner.

In contrast, the Georgia Tech FIDO (Facilitating Interactions for Dogs with Occupations) project aims to support communication between dogs and their handlers. The authors have developed a wearable device which allows dogs to remotely signal to their handlers via a tangible interface attached to a vest worn by the dog [9]. Here the dog takes an active role in deciding whether to engage with the technology. However, in this work the exploration of the design problem space from the perspective of canine usability or user experience is limited to a brief discussion of canine physiological characteristics; moreover it is unclear what role canine users might have had in the design process. With such canine technologies being developed, there is a need to pointedly consider the design process to ensure that the dog's requirements as a user are met. This is important to ensure that the technology appropriately supports canine workers while safeguarding their welfare. Although momentum in designing for dogs is growing, appropriate design protocols still need to be developed.

Animal-Computer Interaction

Animal-Computer Interaction is about researching and designing user-centered technology for and with animals [13,15]. In this regards, there is a growing interest among researchers to develop methodological approaches and protocols to enable nonhuman users, such as working dogs, to participate in the process as design contributors. In relation to canine workers, Helton [7] highlighted how studying their working behavior could help develop technologies to assist them in their tasks. Indeed, Resner's early proposal of a canine-centered design framework [22] carefully considered canine physiological and behavioral characteristics, as well as communication and interaction patterns between humans and dogs. More recently, Wingrave *et al.* [35]'s Canine Amusement and Training game for dogs and their owners, was also directly informed by canine behavioral patterns, partly thanks to the collaboration of an expert dog trainer with the development team. While the needs of the canine users and their humans are clearly taken into account, this research does not question how the dogs themselves might be allowed to take part in the development process.

Recent work in multispecies ethnography [32,14] investigated how the use of wearable canine tracking technology influences the interactional dynamics between dogs and humans. In particular Mancini *et al.* [14] explored the mechanisms by which both parties might make sense of the technology and by which the technology might change them and their relationship. To try and understand what the perspective of the dogs on the technology might be, the authors' methodological framework combines canine behavioral observations informed by ethological expertise and ethnographic accounts from dog owners or handlers who have familiarity with individual dogs. Here we are interested in exploring how such an approach could be applied within the context of specific interaction design projects.

Westerlaken and Gualemi [33] proposed the use of biosensors embedded in the animal's surroundings to measure their vital signs and make ethnographic observations more objective. Although such measures might complement behavioral observations, their interpretation is non-trivial, particularly in relation to an animal's experiences [26]. Measuring biometric parameters more directly indicative of experiential states (e.g. EEG, EMG) still requires the use of wearable equipment sufficiently obtrusive to interfere with measuring. On the other hand, the use of non-obtrusive ambient sensors to measure other parameters requires infrastructures which may be difficult to set-up in field settings, where ethnographic research typically takes place. Therefore, at least for now, ethologically informed observation of the animal's spontaneous behavior and responses to technological artifacts within specific interactional contexts remains the most viable way of enabling animals to participate in the design process.

For exmple, Leet *et al.* [11] employ preference testing techniques developed within animal welfare science to evaluate their haptic wearable human-poultry interface for remote tactile interaction from the animal's perspective. The authors allow their animal participants to choose between different options and measure the strength of their preference based on the animals' behavior. With this in mind, our research takes a multispecies ethnographic approach which combines ethnographic accounts from expert dog trainers or assisted owners with direct behavioral observation within specific interactional contexts.

FIELD STUDIES

We conducted our research at a leading DAD training facility, with the active co-operation of the trainers, clients (who have already been or are waiting to be paired with a dog) and dogs who frequent the facility. Our research aimed at identifying requirements for designing the canine interface of a remote alert system. Consistent with our methodological approach, our fieldwork was organized in three subsequent phases aimed at progressively uncovering requirements for a technology that would enable DADs to remotely summon help for their assisted humans. A key aim of our fieldwork was to identify ways of enabling the dogs themselves to participate in the requirement elicitation process as design contributors. The fieldwork phases were as follows:

1. To begin with our aim was gaining an in-depth understanding of the problem space, and existing practices both in terms of ongoing pre-placement training and in terms of relationship between dog and their assisted human. To achieve this, we spent two full working weeks at the training facility collecting qualitative data about the working environment, daily activities of dogs and humans, and working challenges faced by both. For this phase of the research we gathered field notes, audio and video recordings; and to develop an awareness of the challenges involved we actively took part in training activities by assisting the trainers with various tasks. We relied on these trainers as intermediaries between us and the dogs, and as interpreters of the canine behavior and body language we observed during our time there. Although we did reference canine behavior resources for our own background knowledge, in general we viewed our role in the design space as interaction designers and depended on trainers, handlers, owners, and puppy socializers as the source of knowledge specifically relevant to that particular context. This initial work enabled us to hypothesize design opportunities for potential technological interventions.

2. Next our aim was investigating how the opportunities previously identified could be turned into concrete designs to meet the specific needs of individual dog-human pairs. In particular, in this phase we worked closely with two pairs who were visiting the research facility for a week for training purposes. We spent the week learning more about the health, daily habits and activities, and shared history of the human and canine partners, and directly observing their interactional dynamics both ordinarily and specifically during alerting episodes. We conducted semi-structured interviews with the two clients, and observed both clients and dogs, gathering data in the form of field notes, as well as audio and video. In this phase we did not actively take part in training activities in order not to interfere with the delicate interactional dynamics between the members of established partnerships. The outcome of this phase was the identification of possible features (e.g. shapes, sizes, materials, weight, location, interaction mechanisms) for a canine alarm system.

3. Findings from the previous phase informed the design of a range of prototype canine interfaces for an alert system, which were presented to two dogs (one from the human-canine pair we had worked with and one in early training) in order to explore their requirements. We were seeking to understand the dogs' responses to different components of the interfaces, particularly the mechanism through which the dog would trigger the alarm. We spent several hours, distributed over a period of two weeks, training the dogs to engage with our prototypes, video recording these interactions. Later, we reviewed the video footage together with the trainers to discuss the canine body language. These observations gave us insight into what design features would be appropriate for individual canine users from an ergonomic and cognitive perspective. Through their direct engagement with the prototypes, the dogs gave us an indication of what they might *want* from such an interface.

FINDINGS

Here we show how our findings contributed to our understanding of the design space, the needs of both members of these human-canine partnerships, and how the dogs' participation might inform the design of a canine interface of a remote alarm system.

Understanding the design space

During our initial fieldwork, we studied the daily routine training and social interactions of dogs, trainers, and other personnel at the facility. We specifically aimed to uncover particular challenges the dogs and their assisted humans might face, and whether there might be potential for a technological intervention that could assist the dogs in their work. We wanted to find out what goes in to training these dogs in the first place, and how they alert their humans when they detect dangerously low or high blood glucose levels.

We observed that all dogs at the facility, like many scent detection dogs, undergo "clicker" training. A clicker is an instrument that makes a distinct clicking sound every time a trainer presses it. It is used to reinforce a desired behavior and is one way in which trainers communicate with the dogs during training sessions. At this facility, clicker training follows the popular Pryor framework [21]. Initially, dogs are taught to associate clicking with a reward (usually treats). As their training progresses, the dogs learn to interpret the sound of the click to mean "*Yes! Keep doing that!*" or "*yes! Do that again!*", which thus guides their behavior. In this way, we observed 'conversations' between dogs and their handlers, where the dog was trying to guess the behavior that would result in a click and the trainer would have to be careful to click the exact moment the dog performed the desired action. DAD trainers use this method to teach a dog to distinguish the smell of low blood sugar in a sweat or breath sample (at first in generic biological samples, later in samples from the specific human with whom they have been paired).

If clicker training is done in small enough intervals of behavioral change on the dog's part (e.g. first just glancing at an object, then holding the glance for a few seconds), it can be used to teach behavior that would be very unlikely for the animal to do spontaneously (e.g. staring intently at an object for several seconds, which is how some dogs learn to alert). The following extract from a training session with a young scent detection dog in training, a male black Labrador "D1", illustrates the back-and-forth dynamic nature of clicker training in this context. Here, D1 is at his very early stages of doing click work on scent discrimination and is working with two trainers (T1 and T2) who are co-operating to interpret his performance:

> The dog approaches the first of two lined-up small plastic pots, each of which contains a biological sample with the scent he is learning to recognize. He sniffs the pot and gets a click for this. Out of the dog's sight, the pots are then switched but he approaches the first pot again (which now contains a sample with an irrelevant scent). T1 mentions that D1 is signaling based on a prediction of the trainers' behavior (i.e. that they will always place the relevant sample in the first pot), as opposed to actually signaling because he is smelling the target sample.
>
> In response to this, T1 replaces the pot with a target, and this time, even though D1 noses the target several times, T1 refrains from clicking until D1 has 'held' his attention (nose to the pot) a bit longer than before. Then D1 gets clicked for just examining the pot, with T1 commenting:
>
> T1: "There was a big blow out, then, on the inhalation and exhalation".
>
> T2: "Yes, I saw".
>
> To extinguish the undesirable 'guessing' behavior, D1 is then presented again with an irrelevant sample and T1 tells him that he is a 'good boy' for paying attention to the sample a fraction of a second less. Then the pots are switched again so that the first pot now contains again the target sample. D1 sniffs the pot but T1 waits until he sniffs it again, this time longer, before clicking.
>
> T1: "I'm looking for a difference of behavior [the extension of him staying with the sample versus looking at the (doggie treat) pouch]".
>
> T2: "Yes that makes sense. You want him to show slightly more attention to the scent sample itself before he looks at you expecting his treat- got it."
>
> The next time D1 is presented with a blank he gives it a quick sniff and immediately looks towards T1's pouch, and he is told 'yes' and gets a treat. This happens two times in a row. Next he is presented with target and gives it a distinct sniff, holding his attention half a second longer than the he had for the blank, and immediately gets a click. T1: *"I'm looking for a difference of behavior* [the extension of him staying with the sample versus looking at the (doggie treat) pouch]*".*
>
> T2: *"Yes that makes sense. You want him to show slightly more attention to the scent sample itself before he looks at you expecting his treat- got it."*
>
> The next time D3 is presented with a blank he gives it a quick sniff and immediately looks towards T1's pouch, and he is told 'yes' and gets a treat. This happens two times in a row. Next he is presented with target and gives it a distinct sniff, holding his attention half a second longer than the he had for the blank, and immediately gets a click.

During training sessions like the one above, we noticed that the trainers maintained a continuous dialogue between themselves, checking how the other was interpreting the situation, or getting the other's feedback. Similar to the "talk aloud" technique used in HCI studies, this dynamic verbal collaboration is standard practice for these particular trainers and provided us with a real-time verbal guide to canine body language and allowed us to pick up on some of the subtleties of the training process that we might otherwise have missed. This, in turn, allowed us to identify and later discuss certain requirements with a better understanding (for example, the need to reinforce behavior on discrete actions).

Once the dog has learned to distinguish a particular smell, trainers are able to get the dog to alert when the smell becomes present. We noticed that different dogs alert in different ways. Some alerts are passive, such as a dog sitting by its owner and staring at them in an intent manner. Others are aggressive, where the dog physically jumps on, pulls the clothing of, or nudges the owner until they have their attention. We learnt that dogs are often taught an escalation process, so many dogs will begin with a passive alert and get progressively more aggressive until they perceive that their human has acknowledged their alert. Once they have acknowledged the alert verbally, the human then checks their blood glucose to determine if the dog is alerting correctly. If the blood test confirms that the alert is correct, the dog gets praise and a reward (e.g. a treat, attention, play time).

One recurrent theme we identified was the problem of reliability in recognizing the dogs' alerts. Occasionally, a dog's owner could not distinguish between when the dog was alerting and when the dog was merely spontaneously performing a similar behavior. To address this issue, the practice of teaching the dog to retrieve a particular object, called a bringsel, is becoming popular (see Figure 1). A bringsel is a distinct tube or "U" shaped object that usually hangs from a dog's collar and that the dog uses only in specific circumstances. The concept originated from search and rescue dogs, who were trained to only take the bringsel in their mouth when they had found a missing or injured person. Holding the bringsel in their mouth would therefore unambiguously signal that the dog had found something, thus the handler would be sure of what the dog meant.

Due to the difficulties posed by the training process based on long-term conditioning and associations, we realized that an alarm system should be integrated within existing practices, for example, by embedding new functionalities within objects, such as bringsels, which are already in use.

Figure 1. DAD in training dog holding a bringsel in the typical gesture made to communicate to his handler.

Understanding the partnership's needs

To understand the needs of the users of our prospective alarm system, we worked closely with two clients of the training organization who were visiting the research facility to participate in training sessions with their respective dogs and who had expressed interest in integrating a remote call emergency alarm system into their lives. The first pair was an established partnership, whereas the second pair was a newly formed partnership doing their initial training exercises as a team. Additionally, we interviewed trainers and staff about their overall client demographics, and discussed examples of challenges that many of their clients face related to hypoglycemia alerts. Here we report our findings in relation to one of the pairs we worked with.

The pair included an adult female, C1 with Type 1 Diabetes with a long established partnership with her dog, D1, a male Labrador. C1 had impaired awareness, thus could not always notice signs of impending hypoglycemia. Thus her dog's warnings were especially important to her as they could make the difference between her falling into coma or not. Furthermore, C1 lived in a flat alone with her alert dog, so if she did slip into a coma, no one would be there to call for help, which made prevention critically important. At the beginning of her visit to the facility, C1 reported that she was not sure whether her dog was always alerting accurately. In response to her concern, the training team at the facility observed the dog's behavior throughout the week finding that the dog was alerting consistently correctly, however it was the client who did not always notice her own hypoglycemic episodes since she was already experiencing impaired awareness as a result of her dropping blood glucose levels. Indeed the dog appeared to be highly attuned to the client, frequently looking in her direction or walking over to her and visibly sniffing the air with his nose. Even when the dog was outside playing with other dogs, he would run back every few minutes unprompted, sniff the air around the client, then return to playing. On several occasions the dog was observed getting up close to her face to sniff. Trainers mentioned that while most dogs check on their human periodically, this dog was especially vigilant about checking on his human, and that their strong partnership and bond was clear.

In discussions with the client, we learned that when she did miss her dog's alert and slipped into hypoglycemic coma, the moment she woke up the dog was always right by her side or face, staring at her worriedly. At times the client also would wake up with bruises on her arm that appear to be from the dog nudging and pawing her, presumably trying to wake her up. Medical response teams have also reported that when they found the client unconscious, they also found the dog lying by her side. From this information, the trainers thought that D1 makes an extended effort to wake his owner up and then does not leave her side until she either wakes up on her own or someone arrives to help. In the subsequent phase of our study we realized how D1's attachment to his owner and his unwillingness to leave her side during a hypoglycemic episode would have a drastic influence on the design of the alarm system.

On her part, C1 was used to spending time alone both in and outside her home, for example driving or going on long walks. She therefore felt that the system should be wearable, and specifically requested that such a device would be lightweight and as small as possible. However, such a human requirement was at odds with canine ergonomics, for which a larger and heavier interface would be more appropriate. While for a human a small and lightweight wearable (and perhaps not too eye-catching in order not to attract unwanted attention) interface might be ideal, a dog would have a hard time engaging with such a device: dogs do not have the dexterity of humans and, for example, it is notoriously difficult to train dogs who assist people with disabilities to operate small, fiddly devices such as light switches. Therefore we realized that the design of the canine interface would have to somehow accommodate apparently diverging requirements.

Additionally, as mentioned above, many dogs tend to have a preference for manipulating objects and exploring their surroundings with their mouth, thus a canine interface is likely to need to be 'mouthable' or perhaps, more specifically, 'bitable'. This made us realize that the part of the device intended for the dog to interact with should not contain any electronic components, as these might not withstand the pressure of a dog's bite.

Understanding the dogs' responses

Since our goal was to see how they responded to various design ideas, in designing initial prototypes, we took into account the fact that we would need to test a variety of prototype features with the dogs. To facilitate this, we designed the prototypes modularly, in order for each functional component to be interchangeable with equivalent alternatives. By creating prototypes made of interchangeable components, on a base that could easily be attached to a support (e.g. a wall, someone's belt loop), we aimed to achieve flexibility in the testing process to make the most of our training sessions and limited time with the canine participants. We developed a system with the following three components (shown in Figure 2):

Base: Physically representing a space that could hold eventual electrical components; a 'dummy' of lightweight wood was used. All prototypes had wooden bases with rounded corners for safety and to minimize catching.

Trigger: The electric switch mechanism that will serve to trigger the emergency alarm software. We looked at three different types: a co-called kill switch that triggers upon separation of the two components; a magnetic (reed) switch that triggers upon separation of two components; and a pull-cord switch, that triggers when enough pressure is applied to release the switch.

Bringsel: The 'tuggy' part for the dog to actually take in its mouth and pull on, to trigger the alarm call. This is the one part of the system that the dog directly manipulates to interact with the system.

Figure 2. Physical prototypes used during testing, consisting of wooden base, trigger mechanism, and bringsel, or 'tuggy 'part for the dog to interact with.

During testing, much of our focus was on the ergonomic experiences associated with a range of trigger mechanisms. For example, the strength required for the pulling action, the tactile sensation when pulling, the sound produced by the triggering mechanism, the smell of the materials and other physical stimuli. Specific trigger mechanisms we used include:

• A pull-cord switch (much like those used for pulling a cord to turn on and off a light). This switch made a distinct 'clicky' sound and offered resistance to traction.

• Quick-release "kill" switch, such as those used on motorboats, which attach to the boat operator so that if the operator falls overboard the engine immediately stops. This switch provides little resistance, is lightweight, makes no sound and appears to simply pop off.

• Quick-release magnet, such as those used in care homes for quick-pull alarms. This switch offers more resistance and is considerably harder to pull off.

Testing

Two dogs, D1 and D2, engaged with testing the prototypes. D1 was a certified dog from the partnership referenced above, whereas D2 was another working dog at the facility trained to alert for different scent detection. D1 learned the verbal command to 'pull tuggy' within one training session. He engaged with a hanging pull-cord tuggy that was modeled after the ones already installed in his owner's care home. Initially, the dog was instructed to go 'pull tuggy'; upon which he would take the bringsel part of the prototype in his mouth and pull, producing a click and causing the tuggy to detach. Once he learned this command, the command was paired with a specific behavior on the part of the client (i.e. the client C1 mocking a collapse). D1 quickly associated this behavior with having to go over to the tuggy and pull on it, then bringing it back to C1, who was still laying on the ground. We noted that the trainers expressed interest in taking advantage of the built-in click of one of the prototypes, and of the detaching aspect of all of the prototypes, as a distinct event which could be reinforced in training. In this respect, the system needs to offer the dog two forms of feedback: one is to do with reinforcing the trained behavior and one is to do with informing the dog that he has successfully engaged with the device. The former is a training requirement whereas the latter is an interaction design requirement. In interaction design, it is essential that the system provides feedback to let the user know it has completed an action. We have considered using a clicking noise for this purpose given that it is a sound that the dogs are already familiar with from training reinforcement; however, other noises or feedback mechanisms could be explored instead to avoid possible confusion for the dog. For example, from our initial testing it appears that detachment of the mechanism might be promising. In one instance, when D1 was presented with a detaching prototype with no click, the detaching mechanism failed to work and he could not get it to detach. Rather than give up, the dog continued to pull until he broke the base of the prototype; it appeared that he was waiting for some feedback (either a click or a detachment or both), and continued pulling until this happened (see Figure 3).

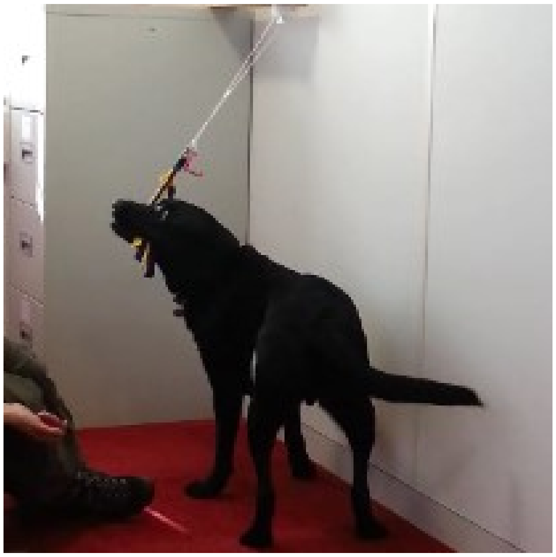

Figure 3. Still image from video showing D1 pulling on the 'tuggy' to trigger the interface mechanism. Here the wooden base is attached to the wall.

Initially, C1 and D1 were in close proximity (approximately 3 feet) from the alarm prototype. However, in real-life circumstances, a client might be anywhere in their home when they experience an attack. To explore this, in subsequent sessions, C1 'collapsed' farther and farther from the prototype, until she was behind a corner. At this point, D1 would no longer engage with the prototype. His walking slowed and he gave hesitant body language, staying by the 'collapsed' client rather than walking away from her. In subsequent sessions where the client was again in eyesight of the prototype, D1 again engaged with it. We concluded that a requirement for this particular dog, is that the device must not be out of the line of sight of his owner when she collapses. We concluded that the dog wanted to be able to keep an eye on his owner as he was used to watching her, while waiting for help or for her to wake up, and leaving her out of his sight even for a moment to engage with the prototype was not something he was willing to do. This further reinforced our observation, in the previous section, that the device needed to have some level of portability, even if the client was only to use it within their home.

In evaluating our prototype with magnetic detachment trigger, we noticed that magnets were useful for their level of customizability with regards to the amount of pressure necessary to cause detachment (e.g. for stronger or more forceful dogs, stronger magnets could be used). However, we observed that the prototypes that use magnets to detach had the side effect of being attracted to nearby metal objects, such as filing cabinets. For example, in an instance where D2 was walking by a filing cabinet carrying in his mouth a bringsel with a magnet mechanism in his mouth, the bringsel was pulled towards the cabinet, much to the confusion of D2. Further consideration and testing will be needed to address these types of issues (e.g. the use of electromagnets could be explored).

Overall, we identified positive and negative aspects for each type of trigger mechanism. Moving forward, design solutions might need to combine different solutions for different functions. For example, it may be necessary to simultaneously employ a separate detachment mechanism to give unambiguous feedback to the dog (as with the magnet solution) with a reliable trigger mechanism to activate the alarm (as with the pull-cord solution), allowing for greater flexibility when designing and when integrating a design into homes with existing alarms (e.g. pull-cord).

DISCUSSION

Our study has shown how a methodology involving dogs, their handlers and their trainers in a multi-species ethnographic approach results in an in-depth understanding of the problem space we are designing for: supporting the work of DADs. In particular, our study has uncovered a number of specific requirements to form part of the design of a canine centered interface for an alarm system for DADs. By working on a specific project this work raises important questions about what it means to be designing for and with canine users.

Designing for Multi-Species Partnerships

Our findings highlight that designing for assistance dogs means designing for a human-canine intimate partnership as a unit. Although this is a symbiotic partnership, each member within it has their individual user requirements between which there may be tensions (e.g. the human's requirement to wear something small and unobtrusive vs the dog's requirement to interact with something 'grabbable' and 'mouthable'). Therefore designing for such multispecies partnerships is a mediation process similar to that which would be undertaken in any interaction design project aiming at developing human technology with stakeholders who have diverging requirements.

These human-canine partnerships share practices to support unambiguous communication between the two (e.g. the use of the bringsel) and we have seen how it is important not to alter such practices in order not to confuse the dog thus compromising their alerting performance, particularly in critical situations. Therefore any technological intervention aiming at supporting the alerting work of the dog needs to be embedded in existing practices and the tools utilized within them (e.g. by developing something similar to a technologically enhanced bringsel). This is indeed consistent with findings from research about the adoption of human alert systems.

Designing for Canine Users

When designing for canine users we need to be aware of their specific needs and capabilities as users. Dogs from different breeds may have different physical (e.g. size) and behavioral (e.g. tendency to bite, tug or nudge; levels of concentration) characteristics for which different artefacts may be more or less suitable. Indeed, when describing the development of a technologically enhanced wearable jacket to aid communication between humans and dogs, Jackson *et al*. [9] emphasize the need to adjust the positioning of sensors on the body of the canine users, to different canine body types.

However, beyond physical and behavioral characteristics immediately associated with breeds and types of dog, our research has highlighted the need to be sensitive to the individual characteristics of the canine user, as shaped by their personality, training and history (e.g. anxieties, likes, dislikes). We have seen that the needs of a dog who has been with his human handler for several years, and who has experienced many problematic hypo attacks, may require a design that is specifically attuned to his anxiety. We argue that designers need to be prepared to listen out for these specific, more subtle requirements, and engage with the dogs as individuals with their particular personalities and stories, in order for a better informed design to emerge.

From designing for to designing with

As we have seen, user-centered design means going beyond just accounting for the physiological or even cognitive characteristics of specific user groups to try and understand the subtleties that make up the individuality of real users and their lives. Participatory Design [24] moves from the assumption that this cannot be achieved without the active participation of the users, that is without bringing users into the *conversation of the design process* But what language should designers use to have a design conversation with dogs?

We have found that rough, interchangeable, thus easily modified prototypes could act as catalysts of such a conversation by enabling us and the dogs to engage in a rapid exchange of stimuli and responses. Indeed, van der Linden *et al.* [30] found that the use of physical prototyping can help both designers and users explore novel interactions which would otherwise be difficult to grasp even when designing with humans. Here it is important to emphasize the possibility of quickly and easily changing the physical prototypes in response to the dog's reactions, in order to maintain the *flow of the conversation*. For example, we have seen how D1 did not appear to fully engage with the prototype until we identified the point at which the detachment mechanism of the prototype offered him enough resistance. We therefore propose the use of *rapid physical prototyping* to enable nonhuman users such as dogs to actively participate in the conversation of the design process. But how can designers interpret the dogs' responses in order to gradually achieve the design that the dogs might want?

Stamp Dawkins [25] proposes the use of behavioral observation as a way of assessing what an animal wants. She argues that understanding what an animal wants is not about interpreting their subjective experience but rather acknowledging what they require based on specific evolutionary adaptations. Perhaps the same might be said of adaptations the animal has developed through training or life experiences which result in the animal demonstrating individual propensities or which a design needs to account for. These adaptations and propensities might express themselves through: readiness in engaging with an artifact or in grasping its functionalities (e.g. being mouthy and pulling hanging objects); repeating interactional patterns in an attempt to complete an action (e.g. pulling repeatedly a cord until a cord breaks); positioning within a space (e.g. sitting next to the collapsed human and refusing to leave their side). We propose that future work in ACI focuses on exploring, articulating and validating such patterns.

CONCLUSION

Using a multi-species ethnographic approach we conducted a field study over three phases working with assistance dogs, their handlers and trainers towards a canine-centered interface design for a Diabetes Alert system. The field study uncovered a number of requirements for such a system, some specifically relevant to the human handler, and others of particular relevance to the canine user. Indeed our investigation showed that we are effectively designing for the human-canine partnership as a unit, which - though intimately symbiotic - may place conflicting individual demands on the design. We also argued that, while it is important that the design process takes on board the specific canine user needs and capabilities, it is now time for researchers to look beyond characteristics directly related to the breed and type of dog. Instead researchers should be prepared to delve into the intricacies of an individual dog's life, their unique personal history, their foibles, and particular likes and dislikes, in order to move towards better informed designs. Whilst this research has focused on the specific example of canine users assisting human users with Diabetes, we anticipate that the methodological approach, and possibly some of the requirements, will be relevant to other assistive partnerships between human and canine users. Through the process of *rapid physical prototyping* sessions, combined with behavioral observation, our research approach critically questions and reflects upon the way in which dogs can participate in iterative interaction design processes. Our research thereby seeks to address the core questions of what it means to design with animals as a part of ACI's wider research agenda to widening participation with non-human users.

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