Designing an Emergency Communication System for Human and Assistance Dog Partnerships

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ABSTRACT
In this research we developed an alarm system that enables assistance dogs to call for help on behalf of their vulnerable owners in an emergency, involving the end users (both assistance dogs and their owners) directly in the entire design process. Here we present a high-fidelity prototype of a user-friendly canine alarm system. In developing the system, we sought to understand the level of support required for a canine user to successfully interact with an interface, finding that the type of emergency a dog is faced with may vary widely and that consequently dogs may have to act on behalf of their assisted owners with varying degrees of autonomy. We also explored the process of conducting usability testing with both canine and human participants, seeking to identify where requirements of one species may overlap with, or diverge from, the other.

Author Keywords
Animal-computer interaction; user-centred design; assistive technologies; canine design; assistance dogs

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous

INTRODUCTION
This paper explores the process of designing a communication system for both human and canine users within a particular design application: an emergency alarm system that enables trained assistance dogs to call for help on behalf of their owners. Thousands of vulnerable people worldwide with conditions such as epilepsy, diabetes or limited mobility, rely on assistance dogs to help them in their daily lives [22, 23]. Recently, many canine-human communication technologies have been developed to enable assistance dogs and others such search and rescue dogs to communicate remotely with humans in order to perform specific tasks. In most of these cases the dogs interact with the technology under the direction of the human. However, when it comes to vulnerable individuals, there are cases in which the human is unable to direct the dog, such as when they are experiencing an epileptic seizure, have fallen, or have gone into a hypoglycemic coma, and therefore the dog needs to take action independently, based on cues he has learnt during previous training. In these cases, when the dog has to interact with technology without human direction, it is critical that the dog is able to make sense of *when* and *how* to use the device to increase their chances of engaging successfully with it.

Thus, our research aimed to understand the factors that might influence the dog's ability to autonomously and successfully interact with a canine alarm system. In particular we wanted to address the following questions: What spectrum of emergency scenarios might dogs encounter which need to be accounted for when designing such an alarm? What design features and interaction mechanisms might help dog users make sense of how to engage with the technology's interface and help them successfully interact with it? How can the design of the alarm support the training process through which the dog learns to use it? What design features are necessary for the human users (dog owners and trainers) of this system? Are there conflicts between the requirements of dogs and humans and, if so, how can a tradeoff be achieved that does not disadvantage canine users?

To address these questions, we developed a prototype alarm and, to ensure that canine requirements were adequately identified and met, we took a user-centred approach to the design process. To this aim, we conducted two studies with potential users of a canine alarm system, to understand the facets of their daily lives and environments, under what

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conditions the dogs might need to perform and how such conditions might need to, directly or indirectly, inform the design of the alarm's interface. While our previous exploratory work [20] identified the need for such a device, and found that for some dogs, a pull-able, detaching interface would be most effective, it did not consider the extent of different types of emergencies. Building on these findings, we developed several high-fidelity prototypes, which we tested with assistance dog users and their handlers, to identify which design features might best facilitate the dog's interaction with the device, and in turn enable the design of the training process through which the dogs learn to use the device as independent agents. We found that when designing technology for assistance dogs, researchers need to consider to what extent the dogs might be expected to drive the interaction. Depending on the degree of autonomy expected from the dog, researchers need to design not only to support the interaction itself but also to facilitate the training process that will eventually lead to the dogs being able to interact with the technology.

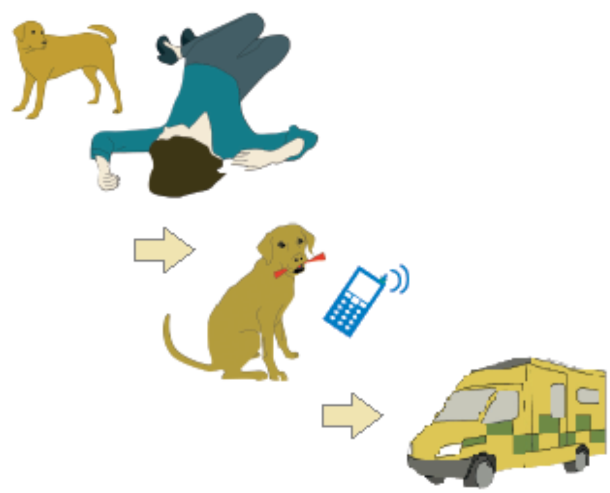

Figure 1. A model of our system whereby a dog is commanded or relies on a cue to activate an emergency alarm.

RELATED WORK

The work of assistance dogs

Even as increasingly advanced assistive technologies become available, assistance dogs are growing in demand, with national waitlists often stretching years for a certified dog. However, some individuals' conditions can be so brittle that even the support of an assistance dog (or the aid of assistive technology) does not always prevent emergencies that require outside intervention [4, 8]. For example, while diabetes assistance dogs are trained to alert a person when they are about to have a hypoglycemic attack, such attacks can be so sudden that the person has no time to respond to the dogs' alert. As a result of the emergency, the person may experience a fall or seizure. Many assistance dogs are taught to seek help or bring a cell phone in response to falls or seizures [1]. For such emergencies, fall detection and seizure detection devices also exist, however many individuals can have a medical emergency that does not involve falling (such as slipping into hypoglycemic coma whilst sitting on the couch) so it goes undetected by such devices [11]. Consequently, ambient or wearable devices may not always properly respond when an emergency occurs.

Technology to support human-dog partnerships

A variety of canine-computer communication devices have been developed in recent years [6, 7, 9, 16, 19]. Among applications relevant to this research, Ferworn et al. have created vibro-tactile wearable vests to "augment" search and rescue dogs that wear smart devices allowing their handlers to direct them remotely when they are searching through rubble for victims [5]. Similarly, a system to support "cyber enhanced" search and rescue dogs has been developed to send vibro-tactile information remotely from human handlers to search and rescue dogs, and sending various sensor information back to the handler to allow them to monitor the dogs' position and biometrics [2]. Additionally, wearable robotic movement detection and voice communication devices have been developed for working dogs that allow handlers to communicate information to their dogs remotely, for example which direction the handler would like the dog to travel in a search and rescue situation where the handler is not with the dog as it searches but rather directing from a different location [14]. Similarly, Byrne et al. have conducted experiments to measure working dog's ability to perform distinct tasks in response to the vibrations produced on their bodies by wearable systems [3], allowing "remote control" of the working dog. And, the COCHISE project has sought to create an "augmented" assistance dog by using a machine as a mediator that translates the dog state to the human user and also allows the human handler to ask for a command via the machine [21]. All of these technologies allow human handlers two main functions; to 1) communicate with the dog and 2) monitor the dog to support it in doing his task. However, they all rely on the human handler being in a state that allows them to interact with the technology themselves, which may not be possible in emergencies. Thus, our work seeks to explore more autonomous interaction.

Other work has indeed explored more active interaction from dogs, where the systems enable working dogs to remotely communicate information back to their handlers via an active interaction that the dog initiates [12, 20, 26]. In these systems, the line of communication goes not only from the handler to the dog, but also from the dog to the handler, allowing the dog to become an active rather than passive user. In particular, our own past work has investigated requirements for the design of a canine alarm system that would enable dogs to summon help (for example, family members or health services) during emergencies, finding that many assistance dogs respond well to an interface with a detaching mechanism, which effectively allows them to perform a 'retrieve' task to trigger the alarm. But, while this work explored ergonomic issues relating to the system's interface design, it did not take into account the range of situations in which the dog might need to use the device in the wild, the different challenges that each situation might raise for the dog, and what role the design of both the device and training process might play in addressing these challenges. To investigate these research issues, we build upon this work, using the findings as a starting point to address a number of outstanding questions and take the work further.

METHODOLOGICAL APPROACH

To address our research questions, we have conducted two interdependent and complementary studies with prospective canine users and their assisted humans.

The first study sought to understand the daily lives of assistance dogs and their humans, and challenges they faced, what kind of emergency situations they faced and how the dogs were dealing or expected to deal with those emergencies. We conducted situated interviews with four existing owner-dog partnerships. The findings from this study informed the design of a number of prototypes, which we then tested with both dogs and humans.

The second study was directly informed by the findings of the first study and aimed to understand usability issues and design preferences for dogs and humans (both trainers and owners). To enable both dogs and humans to take part in and contribute to the research, we presented different configurations of our prototype to assistance dogs and their trainers for use during training procedures. The study involved several iterative cycles of prototype modification and evaluation to incrementally improve the design. The findings from this study highlighted the role of the interface design in enabling the dogs to successfully engage with the device, and in facilitating the dogs' learning process within the training context.

STUDY 1: UNDERSTANDING THE CHALLENGES IN EMERGENCY SITUATIONS

In order to understand the context in which our alarm would be used, we interviewed prospective end users. Existing assistance dog partnerships were identified and recruited through a UK-based assistance dog training organization. One assistance dog-owner partnership that had participated in the 2014 exploratory study [20] was invited to participate in this study as well (O4/AD4). All other participants were new to the project. The participants (Table 1) were interviewed on multiple occasions both at the assistance dog training center and in their own home. The dogs were represented by their owners, who informed us on their routines and behaviours. We also observed the dogs directly, during their basic training and tasks. We spent approximately a total of ten hours with each partnership over the course of six months.

Partnership	Dog Breed	Owner Living Situation	Lifeline etc alarm in home?
O1/AD1	Labradoodle	Lives with partner	no
O2/AD2	Labrador Retriever	Lives with partner	no
O3/AD3	Labrador Retriever	Lives by self	yes
O4/AD4	Labrador Retriever	Lives by self	yes

Table 1. Client and dog partnerships for study 1.

Participants: Assistance Dog and Owner Partnerships Overview

We refer to the participants as Ox for "owner x" and ADx for "assistance dog x".

O1 is an adult male with Type 1 Diabetes who lives with his partner and his male Labradoodle Diabetes Alert Dog. Both O1 and his partner are retired. Due to complications of diabetes, O1 uses an electric wheelchair, thus AD1 is also trained as a Mobility Assistance Dog. AD1 is able to detect changes in O1's blood sugar even at night, and will attempt to wake up O1 to warn him of the medical emergency. If he is unable to wake O1, he is trained to attempt to wake O1's partner by nudging or pawing.

O2 has Type 1 Diabetes and resides with her partner, her pet dog, and her Diabetes Alert Dog, a male Labrador AD2. Before she was placed with AD2, O2 had episodes of being unconscious for hours at her home when her partner has been out or travelling and she has found herself alone. O2 has reported that since being placed with AD2, she has experienced a significant improvement in her quality of life.

O3 lives with her Diabetes Alert Dog, a female Labrador Retriever. As a complication of Type 1 Diabetes, O3 experiences seizures when her blood sugar goes low. O3 often wakes up to bruises on her arms from her dog repeatedly trying to wake her up during the hypoglycemic episode. Therefore, O3 hopes that AD3 can learn to trigger some sort of alarm, and has specifically requested the assistance dog organization to train AD3 how to press a phone button on her behalf in emergencies.

O4 also has Type 1 Diabetes. She lives alone with AD4, a male Labrador, in a care-apartment which has built-in alarms that she can activate in an emergency by pulling a cord. When her blood sugar is low, O4 often experiences "unawareness", becoming disoriented prior to falling into a hypoglycemic coma. O4 has had many instances of emergency services visiting her home when friends and family cannot get hold of her and call an ambulance.

In addition to the above basic profile information, we also asked each partnership specifically about the circumstances that had led up to emergencies that they had experienced. Some examples of the questions we asked are: How often do you experience minor emergencies (where minor implied a friend, family member or neighbor was able to handle the situation)? How often do you experience major emergencies (where emergency services were called or the hospital was visited)? How much memory do you have of the emergencies? What symptoms do you display leading up to, during, and after the emergency? Do episodes usually happen in the same part of the home or at the same time of day? How has your dog responded to these emergencies? From this information, we were able to begin to understand the potential contexts of use of the alarm system.

Findings

Types of Emergencies and Canine Responses

We found that emergencies could present themselves in very different forms, both over time within the same partnership and across different partnerships. Here we describe the main patterns we have identified.

Level 0: No outside help is required. Here no emergency arises: as usual, the human experiences an episode, but the assistance dog is able to assist them, so that no outside help is required. For example, O1 is sometimes weakened from complications of diabetes and unable to move his wheelchair over a bump in the flooring of their house. However, his mobility assistance dog AD1 is able to tug the wheelchair over the bump for O1, so O1 is not stuck and does not need the assistance of another person. In many situations, the person's medical situation may allow them to respond to the emergency themselves without the need of outside assistance. For example, O2's dog alerts her of dropping blood glucose levels. O2 then tests her blood glucose levels and is able to verify whether they are dropping, having been warned by the dog when she might not have otherwise tested. In this way, O2 is able to respond to the potential medical emergency before it degenerates such that outside help is required.

Level 1: Outside help required, but handler is able to direct dog. For example, O1 would occasionally become stuck or experience a mobility problem when alone in his house. When this happened, he would direct his assistance dog to press a button which would call his partner who could then come and help him: *"it must have taken him 8 hours to learn, so quite a while, but once he learned how to target a button, it could be done. I'd just keep asking him until he did it. Once he hit the button, it would call [my partner]."* Here, we see cases where the handler is physically incapacitated but mentally fully functional, so they are able to either verbally and/or gesturally request the dog for help. In this situation, although the interface should still be as intuitive and easy to use as possible, the dog is not required to understand the actual purpose of the object. They only need to understand that they are being asked to perform a particular task.

Level 2: Outside help is required, and handler is not able to direct dog with commands, but exhibits distinct behaviors that dog has been trained to respond to. With emergencies at this level, the handler is unable to request help directly, but, crucially, they still display some sort of distinct behavioural cue that the assistance dog has been previously trained to react to. For example, due to the debilitating nature of the seizures, even if O3 is close to a phone when she begins seizing, she cannot operate it: "*Sometimes I will drag the phone onto the floor, to dial 999. I've got memory buttons…if I could manage to press the memory button, it used to go to my neighbour who lived across the road who would come and sort it out.*" Describing why she did not use a wearable alarm, O3 said: "*They give you a strip that's big enough to literally just go around your wrist...so when you're spasming, the elastic is going, pulling out and the minute that its out, it's gone...it's gone.* In this situation, O3 exhibits a behaviour she would never exhibit in a non-emergency, so trainers can train AD3 to respond appropriately whenever O3 exhibits this behaviour. Similarly, O4 often has her blood sugar drop extremely fast and is unable to prevent hypoglycemic coma. If she is standing up or moving around when this happens, she will suddenly collapse to the floor. This behaviour, of a sudden fall to the floor, is also a distinct cue that the dog is able to respond with, because it is not something that would happen in a non-emergency. Again, this means trainers are able to train the dog to react in certain ways when the handler drops suddenly.

Level 3: Outside help is required, and handler exhibits little outward behavioural cues and becomes unconscious. This is the most extreme end of the spectrum, where the dog finds itself with a handler who is only experiencing an emergency and is also completely unable to direct their assistance dog or to even exhibit distinct behavioral cues. For example, O4 sometimes is sitting on the couch watching television or resting, or even in her bed at night, when she goes into a hypoglycemic coma. Here, the signals indicating an emergency requiring external help are much more subtle, and it is possible that the dog will need some understanding of the device's purpose to successfully interact with it. The dog is likely to at some point understand that their owner needs help, however without the handler's guidance or specific behavioural cues will have to take control of the situation and decide whether to call for help. Thus, if a device was available for this purpose, the dog might need to be able to associate its use with the arrival of outside help, in order to reliably engage with the technology at the appropriate time.

Emergencies spectrums, usability and learning

The types of emergency that our participants experienced always appeared to vary along the spectrum outlined above, depending on the client, their dog, and the individual emergency situations. What varies along this spectrum is the way in which the sensemaking and decision-making burden is distributed between the two agents: the human and the dog. At one end of the spectrum, the human is in charge and the dog simply physically implements their directions. At the opposite end of this spectrum the entire burden of making sense and dealing with the situation is on the dog, while the human is out of the picture (e.g. because they are entirely unconscious). The more responsibility the dog is expected to take in a situation, the more the design of an alarm the dog was expected to use would need to ensure that the dog is enabled to autonomously engage with and operate it. A successful design will bridge the cognitive leap the dog needs to make in associating the action of triggering the alarm with the effect of his action as much as possible. Because it is not possible to verbally communicate to the dog that "if you activate this alarm whenever there is an emergency, help will come", the function of any such device would have to be communicated to the dog via training. It is precisely via training that the dog learns to associate his interaction with the device with its effects. We discuss later how these training sessions start at one end of the spectrum and go as far as they need based on what kind of emergency their owner is expected to experience and therefore in what context the dog will have to use the device.

Access, Use and Misuse

In addition to describing types of medical emergencies and how they may present, we asked the assistance dog owners where in the home emergencies were mostly likely to happen. Each participant had a different answer to this question; for O3, it was in the bedroom, for O2, it was upstairs, for O1, it was "*about as equally likely anywhere in the house*", and for O4 it was "*usually in the sitting room, but could be anywhere really.*" In this regard, each participant wished the dog to always have access to the alarm. O3 asked "*So she can always get to it, right?... Because I could go anytime, I do go anytime*..."

However, enabling the dogs to always access the alarm to account for the unpredictability of the emergencies' location raised issues about possible misuse. For example, O2 said "*so how many people would [a canine alarm system] be able to call? I might need to warn them if the dog is trigger happy...*" In general, across those we interviewed, there was a concern that, if the dog used the device when not appropriate, friends, family, or emergency services would be alarmed when actually there was no problem. We thus evaluated our options to approach dealing with false alarms. We had already ruled out part-time physically restricting the dog from the alarm due to the unpredictable nature of the emergencies, determining that it was better for the dog to have *too much physical access to the system rather than not enough*. Another approach would be to make the alarm less enticing for the dog to use, so that even if they could always physically access the alarm, they would not be tempted to engage with the alarm unless they were triggered to do so by a verbal or behavioral cue. For example, rather than making a very inviting interface that the dog found easy and even pleasurable to use, we could design something more challenging so that they would not be tempted to use it for fun thus creating false alarms. However, this is also problematic as it could potentially backfire and result in the dog not being able to engage with the alarm during a real emergency. Thus, we decided to take different approach to handling false alarms, which was to add functionality that allowed the user a reasonable (configurable) amount of time to get to the alarm after the dog had triggered it to cancel it. Following from this, another requirement of the system emerged, namely the requirement that the alarm must make some sort of sound, so that if the dog triggered it whilst in another room the owner would be know that it had been triggered. We also realized that, if following a false alarm the owner could not get to the device in time to cancel it, their friends and family would be worried needlessly. We thus added a requirement that if the alarm was cancelled "too late" during a false alarm and texts had already been sent out, follow-up notification calls and texts would be sent to the emergency contacts.

Figure 2. A canine alarm prototype used to test with the dogs and their trainers (displayed with different canine attachments).

THE ALARM PROTOTYPE

The design of our system (Figure 2) was based on the findings of study 1 and on our previous work [20]. It featured three main modules:

1) An electronic component that encapsulated the system's hardware and ran the system's software. This was built on a Raspberry Pi B+ and Arduino Leonardo. The Arduino was used for input and output control and the Pi to control audio and internet connection. This configuration was chosen to allow for optimal flexibility in making changes to the alarm. For example, with this configuration it was easy to

add or modify output features, such as sounds or lights, or input features such as buttons.

2) A detaching component that the dog could pull off to trigger the alarm. This was based on previous findings by Robinson et al. [20], according to which mouthing and pulling on object is more intuitive and ergonomically appropriate for some dogs as opposed to other modes of interaction such as pressing a button with a paw. The pulley could be easily changed depending on individual dogs' physical characteristics and personality.

3) A trigger that was connected to both the pulley and electronic component and that activates the alarm upon detachment. Robinson et al. [20] had found that the pulley's complete detachment worked as unambiguous feedback for the dogs, letting them know that they had completed the task of triggering the alarm. Therefore, our alarm featured a quick-release mechanism that activated the trigger when the pulley became detached by downward traction.

STUDY 2: ASSISTANCE DOG TRAINING AND TESTING WITH ALARM PROTOTYPES

From the first study, we understood that the dog's interaction with the alarm may be cued in various ways and that the dog may need to interact with it with varying levels of autonomy given that it cannot be taken for granted that the emergencies experienced by each partnership will always correspond to one of the 'levels' we have identified, i.e. each partnership may experience emergencies the require the dog to act with different levels of autonomy.. However, with this particular study sample, all human participants had experienced at least one 'level 4' type emergency, that is, one where they were completely unconscious and the dog was alone. This is likely a result of the fact that the charitable organization we worked with tends to place assistance dogs with people that need them most, that is, with brittle Type 1 Diabetes, and thus those that are at greatest risk. Therefore, it made more sense for us to focus our design efforts on a 'level 4' scenario. Additionally, while focusing on such a scenario presented the greatest design challenge, it also had the greatest potential to make a significant difference in a most dangerous situation. By designing a device that afforded and supported autonomous use by the assistance dog, we would afford the dog greatest capacity to always avert the consequences of emergencies.. In order to achieve such a design, we worked with assistance dog trainers and trained assistance dogs, and tested our system with them to evaluate its usability both for human and dog users. Four different assistance dog trainers and tester dogs were recruited from the same assistance dog organization as in study one. Two dogs that participated in study 1 also participated in study 2.

Participants: Trainer and Assistance Dog Partnerships Overview

Here, we identify the dog testers with TDx meaning "tester dog x" and Tx meaning "trainer x", etc.

TD1 is a female Labrador cross that is not a placed assistance dog, but rather a dog trained with assistance dog skills that lives full-time with trainer, T1.

TD2 is a male Labrador that is a pet dog with specialized training that lives full time with an assistance dog trainer, T2. TD2 followed a very similar training process to TD1.

TD3 is a female Labrador (AD3 from study 1) that had been trained as a Diabetes Alert Dog, for a client that has Type 1 Diabetes and hypoglycemic seizures. TD3 was trained by T3 to use the alarm in preparation to install the system directly in the home for testing purposes.

TD4 is a male Labradoodle (AD1 from study 1) who is both a Mobility Assistance Dog and a Diabetes Alert Dog. TD4's owner uses a wheelchair.

Partnership	Dog Breed	Cue for interaction
T1/TD1	Labrador	Collapse cue
T2/TD2	Labrador	Collapse cue
T3/TD3	Labrador	Verbal command/seizure
T4/TD4	Labradoodle	Verbal command

Table 2. Trainer and dog partnerships in study 2.

Training protocols

To build up a dog's understanding of what the interface could do and how he could interact with it, training sessions aimed to gradually communicate to the dog the mechanism by which they could complete their task (detaching and retrieving the tuggy from the interface) and the situational context for when they should do this

All dogs in this study already knew how to 'tug' and retrieve on command. Here the challenge was teaching the dogs to do the same following a situational cue rather than a verbal command. To achieve this, the verbal retrieve command was *chained* (used at the same time as the action performed by the handler so that the dog could associate one with the other) to a human behavioral cue. Behavioral cues can vary depending on the context of expected emergencies, for example the trainer may simulate fainting and collapsing on the ground as a behavioral cue, or they shake as one would during a seizure. Acting out these emergency-like behaviors during non-emergencies teaches the dog to recognize these actions as training cues rather than a reason to be distressed. Then the verbal command is dropped and the trainer need only perform the behavioural cue and the dog will know to retrieve the detachable tuggy and bring it back to the handler. The cues can then be made incrementally subtle. For example, the trainer can merely slouch over whilst sitting rather than falling dramatically to the floor. These more subtle cues are intended to correspond with a "level 3" emergency as earlier described; that is, there is no obvious or sudden behavior that the handler will demonstrate to indicate to the dog that it should interact with the alarm system.

Testing Process

For each assistance dog and trainer partnership, we held testing and feedback sessions whereby the dog was encouraged to engage with the system with varying settings and with varying cues. We observed both spontaneous and instructed behavior in the dogs, and recorded feedback from the trainers interpreting the dog's actions and responses. The dog and trainer partnerships were presented with different iterations of the prototype across the span of several months.

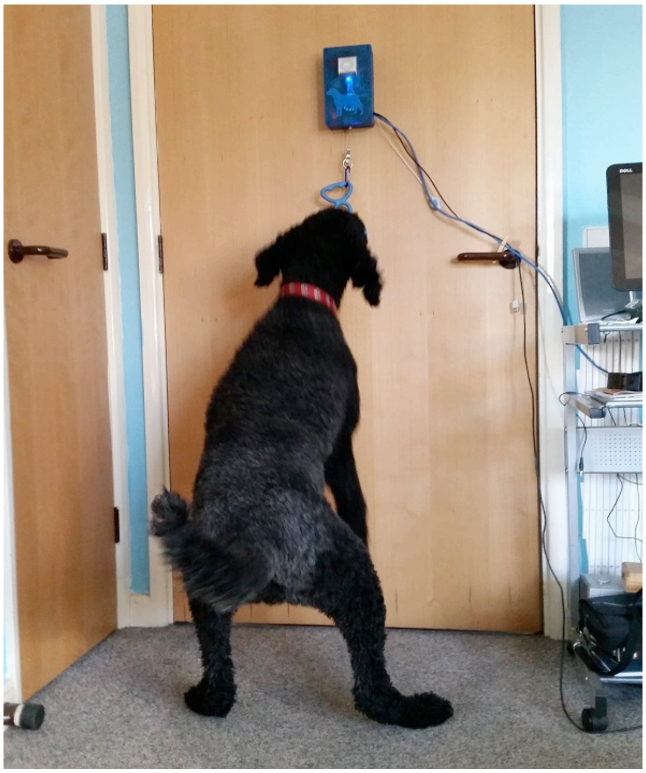

Figure 3. A tester dog triggering the alarm on command.

To identify design features, we asked trainers to tell and show us what about the interaction with our system prototypes seemed particularly easy for the dog, versus what might have been less so. Through the trainers' description of the training protocols and process to us, we were able to understand not only how the dog would engage with the device, but also how the dog *would learn to engage w*ith it. This is important because, for many levels of emergency, we found the training process to be intertwined with the dogs' ability to use the device in an actual emergency; if the dog did not associate the alarm with a particular context, he would be unable to correctly use the alarm and the design would fail. Additionally, we asked the trainers about their understanding of how the system worked and how usable they thought it was, from their own user perspective, for the purpose of training the dogs, independently of the perspective of the dogs. We were especially interested in understanding where these canine and human requirements overlapped, and whether any tensions existed between the two and, if so, what tradeoffs might need to be made.

Figure 4. A tester dog returns the tuggy to her trainer who has "collapsed" in a training session to cue the dog to pull the tuggy off the alarm.

Findings

Here we present findings pertaining to how the assistance dogs interacted with our alarm system prototypes, and the relative implications for the system's design, both in terms of canine and human requirements.

Detachment Resistance and Playfulness

For all canine participants, we observed a correlation between the force required to detach the tuggy and the playful behavior that was observed. TD1 especially displayed playful behavior when initially interacting with the tuggy. As training progressed, TD1 became overall less playful with the object (demonstrated by less head shaking), possibly because some of the novelty of the play interaction wore off as training continued. Of the four tester dogs, TD2 was especially forceful with his pulling of the tuggy on the alarm. Said T2 of TD2: *"He'll pull as hard as he needs to pull on that. Nothing will be too strong…"* T1, T2, and T3 all mentioned that it would be helpful to have three or four "pressure setting choices" to use with different dogs or at different stages in each dog's training, while T4 said that as long as TD4 understood the task, the amount of tuggy resistance would not matter. Indeed, regardless of the different levels of resistance we tested with, TD4 displayed similar behaviors during the interaction, indicating this design variable did not have a significant effect on TD4's training process.

Mounted height

For testing, we were able to adjust our prototype's mounted height by using super-strong velcro tape instead of drill mounting. We adjusted the height on the wall based on observations of the dog's interaction. For example, TD4 struggled to engage at lower height settings, as he could not get leverage when pulling the tuggy down and needed the height to be adjusted appropriately. This implies that a final design would need to either feature height adjustability or be mounted at optimal height for particular canine users at the time of installation.

Material and Size of Tuggy

We observed that different dogs responded more or less positively to different types of detachable tuggies. For example, TD2 required a less 'appealing' shape than the other dogs, because if more toy-like tuggies were used, he would attempt to engage with the alarm even when not prompted by the trainer. It seems that for some dogs one may need to use a less enticing object than for others, particularly for those who find the pulling action itself rewarding. Also, we noted that what constituted "enticing" varied across our tester dogs. Therefore, all trainers felt it was important to be able to interchange different type of tuggies independent of the rest of the interface.

Environmental Distractions

We also found that to successfully trigger the alarm in an emergency situation, the dog may need to overcome environmental distractions and challenges. For example, in one training session, when T4 collapsed with other dogs (that were not trained to use the alarm) in the room, they interfered with TD4 while he was attempting to engage with the alarm. Although he had previously been able to trigger the alarm without hesitation, with several other dogs attempting to play with him, he seemed confused as to where the alarm was located. Once the other dogs were prevented from interfering, TD4 again was able to go back to his previous working mode and correctly pull off the tuggy from the alarm, and correctly return it to the fallen T4. TD2 too became distracted when he took part in one testing session when other dogs were present in the testing environment. Once distracted, he picked up other objects that were laying around and that were similar in size and shape to the tuggy hanging from the system. This indicates that uniquely characterizing the special meaning of the tuggy in a way that makes sense to the dogs may be necessary, considering that assistance dogs do operate in all kinds of environments and amidst a range of possible distractions.

Directional Traction

Although human testers tested the quick-release of the alarm trigger without breaking it, three of the four tester dogs broke the initial version of the quick release numerous times. T2 observed "*he [TD2] doesn't understand how to use it properly!"* While human testers all pulled directly down on the quick-release, the dogs sometimes approached the quick release with a lot of force pulling from different directions, which the initial quick release design did not account for. This implies that the quick-release needed to tolerate being jostled around and pulled from any angles away from the device. To account for this, we made three different changes to the quick-release's design and materials throughout the study.

Compact Design

Our initial prototypes had multiple component boxes each holding a different component of the system (the Arduino, the Raspberry Pi, the switch, and the speaker) separately, connected by cords. From our perspective, such a modular approach was desirable to enable rapid prototyping. However, trainers reported feeling intimidated by the complication and sprawling appearance of the apparatus. Additionally, two of the four dogs at one point got caught in the cords, which of course severely disrupted their interaction with the device and consequently their performance. Although, as designers, we had deemed the cords to be unobtrusive, this was clearly not the dogs' experience. Thus we had to give up the modularity of the electronic components and place them all in one box, with only two cords (one power source cord, and one ethernet connection cord) coming out of it.

On-board Non-adjustable Speaker

From study 1, we had found it to be a requirement that the alarm used sound feedback to indicate its state, specifically to let the user know when it had been triggered, even if they were in a different room from the alarm. We thus had included a robotic voice that repeats a configurable message when the alarm has been pulled (for example, "*Dog has triggered alarm. Dog has triggered alarm....*") While we initially expected the dogs to be reactive to the sound feedback from the alarm, no dogs displayed differences in behavior in response to the sound being on or off. No dogs were observed to behave any differently between an alarm that was creating this sound after it had been activated and one that had not. This could imply that the sound feedback was simply not important to the dogs, or that the particular sound and volume of sound was not important but other volumes or sounds may be. Because of the sound did not seem to matter one way or another, our prototypes were changed to have the speaker automatically functional, such that if the device had power it automatically had the volume turned up high. This was to prevent the human user to forget turning the speaker on and off with each use.

Colour-coding and light patterns for status feedback

All trainers in the study at some point expressed confusion as to what state the device was in with the initial prototype, which did not include any light feedback. To account for this, lights were added with different colour-pattern combinations to allow the human users of the system to know what state the alarm was in. The system was updated to have:

- a solid blue light to indicate that it was successfully connected to the internet and ready to work;
- flashing blue light indicated that the alarm was working locally (i.e., would still create noise if triggered), but that the internet connection was broken thus could not make calls or SMS;
- a red blinking light indicated that the dog had triggered the alarm, but outside calls had not been made;
- a red solid light indicated that the dog had triggered the alarm, and that the outside calls had been made (i.e., the window of opportunity to cancel the alarm had passed).

Similar to the sound, the tester dogs did not seem to react to the addition of the lights in any way. Thus we considered the lights a feedback feature only for human users, although it is possible that over time the dog would associate the device to have lights and be confused it if it suddenly did not.

DISCUSSION

We have seen that in emergencies, assistance dogs have to react in a range of situations. When developing a system that allows the dogs to call for help, designers should consider the contextual use of the actual system for end users, and also consider that design features need to facilitate the interaction and the training process that will enable the dog to know when the interaction is necessary. Below we highlight some lessons learned from this particular design application and design process that included the dogs, their owners, and trainers in the process.

Canine and Human Requirements

Flexibility and requirements

This work has identified a need to recognize both canine and human users' requirements so as to understand what tradeoffs between these, if any, need to be made. In general, we found that our human users were more flexible than canine users in their interaction with the system. Of course, we could not just verbally explain to a canine user how or when to use the alarm; he had to learn this through a complex training process tailored to the dog's ability to learn the task at hand. That is, rather than verbally instruct the dog to change its physical way of interaction, in this case their way of pulling, we needed to change something about the device to account for the dog's needs. And, in a situation where there was tension between the dog's requirements and the human's requirements, we found the former needed to be prioritized- as, if they were not able to interact with the system when necessary in a real life emergency, the design had failed. For example, from our first study, we found out that each participant had many stakeholders involved during an emergency and if the dog successfully triggers an alarm, it would potentially impact many other individuals. Friends, family, neighbors, and emergency services could potentially be contacted by mistake in a false alarm, causing un-necessary worry or resources to be tied up. In order to solve this tension, rather than making the interface harder for the dog to use, we accounted for this issue by building a configurable cancel and message system to serve as both a way to prevent false alarm contact being made, and also as a way to rectify the situation (follow-up messages) if the contact was allowed accident. This is one example where we were able to compromise canine vs human requirements; rather than insist the canine user always be correct with their interaction, we made the system more complex for the human user in order to keep the canine user's experience as straightforward as possible. On the other hand, we found sometimes there is no tension between requirements. For example, the dogs uniformly ignored the different colors and flash patterns of our prototypes lights, while in contrast the human participants reported that the addition of these lights as a form of feedback considerably improved their understanding and comfort level with the system. Similarly, while the dogs appeared to respond very differently to different material or size of tuggies, the human's user experience were not affected by this element of the system. We conclude that for future projects where a technology is developed for a canine-human partnership, during the design process, requirements can be flagged as canine or human, where there is either overlap (thus tradeoffs are required), or where they are divergent.

Designing for independent use

From the first study, we identified that there is a spectrum of cues that the dog may use to know when to trigger the alarm, depending on how the owner and the dog experience the emergency. These cues can range from straightforward (the owner pointing to an alarm that is close by and asking them to trigger it), or very challenging (the owner simply slumping over unconscious when already seated, and the alarm being located in a different room). We also saw that for this particular device, the most challenging level, when the owner is completely unconscious, is always a possibility. Thus we must try to create a design that is most effective and usable for the dog in this situation. Depending on the context of use, the dog will need to understand how and when it is appropriate to use the device before an actual emergency situation arises. For example, during the second study, one canine participant was distracted during a mock emergency training session, and rather than retrieving the attachment from the canine interface, the dog picked up a similar shaped object (a dog rope toy) from the floor. Notably, this dog was not being directed in any way, because the emergency situation was being staged. Thus the dog was trying to figure out based on prior training and the current situation what the best action was to do, and was not able to do so. This could indicate that through various characteristics of the interface, we need to provide greater clarity to the dog that the interface has special meaning so that the dog does not become confused. By integrating testing into “real life” training scenarios, we can come close to seeing how the dog would interact with the device on their own. Further testing could include camera footage rather than observation to further expose issues with autonomous use. Indeed, additional features may surface with continued testing in these situations. By having a system that allows for adjustment such as height, materials, and location within the home , designers can provide dog trainers with additional tools to convey meaning to the dog as to when and how to use the system. In this way the system can support the training process rather than create additional challenges for the trainers and owners.

Canine experience and participation

We have seen that even basic design aspects, such as the height the device is mounted, the materials used, and the connection of the activation mechanism, have a significant effect on usability for assistance dog users. For example, a large, soft toy shaped tuggy may convey play and positive association, as well as an affordance to tug. Or, a ball attached to the end of the tuggy may encourage the dog to bring the tuggy back to its handler because it expresses a ‘retrieve’ affordance for the dog. An interface positioned at a certain height may invite the dog to engage with it whereas other settings may discourage the dog or challenge them ergonomically to engage. While working with a different species undoubtedly slows down the design process due to interspecies communication barriers, teaching already well-trained assistance dogs to use the system was comparatively straightforward and certainly worthwhile. Although with untrained dogs and other animals the research process may become increasingly challenging, our findings highlight how experiential differences between species mean that the animals’ participation play a fundamental role in the process and provides a significant contribution to the development of a successful design. While our findings highlight the need to directly involve the dogs in the testing process when developing a system intended for them in order to uncover specific canine affordance, they also confirm [16,20] the need for designers to work with canine behavioral experts as mediators and interpreters of canine requirements. Of course, canine behavioral experts are humans too and if interpreting the behavior of other species was a straightforward practice, many issues in the field of animal welfare would not still be as debated as they are. Such margin of uncertainty in understanding non-human users highlights the necessary nature of multispecies interaction design as a process of iteration and slow approximation, in which the participation of all interested individuals is of critical importance.

Wider Applications

This research specifically focused on designing an alarm system for assistance dogs and involved dogs of similar background and physical characteristics. However, other modes of interaction might be more appropriate for different sizes, breeds, personality of dogs. The process of looking at not only the ergonomic interaction for a canine user, but also the context of the interaction and training required to interact with the device, can potentially be applied to other design applications to produce different interfaces that have been similarly informed by the dog's need as a user and the trainer's needs. Additionally, the particular interface we describe here could serve as a guideline to develop interfaces for other uses where dogs and humans need to communicate, or where a dog needs to accomplish a task physically on a human's behalf or for their own purposes. It is worth noting that all of the dogs in our studies were assistance dogs placed with owners with Type 1 Diabetes. Different types of assistance dogs receive different training and have different relationships with their owners, further work conducted with different user groups (different types of assistance dogs) may uncover additional requirements or modes of interaction Thus further work should expand to include other breeds and types of assistance dogs and explore other modes of interactions, continuing to take a user-centred approach to different canine users, and to identify where if at all tradeoffs are required between human and canine requirements.

CONCLUSION

This paper has drawn from user-centred design research with assistance dog-human partnerships to develop a system to enable assistance dogs to call for help remotely when their owner becomes incapacitated and is unable to do so themselves. This is one instance of potentially many where a well-designed system intended for canine use can allow a working dog to accomplish a specific task, which might have been difficult or impossible without such a system. In our design journey we have found that emergency situations may vary greatly and that dogs may sometimes be able to help their owners under their direction but other times have to take charge of the situation and act autonomously. We have discussed how, when designing interactive systems for dogs, researchers need use design features both to provide canine users with the necessary affordances and also to provide trainers with elements that can facilitate the training process.

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