Animal-Computer Interaction: Designing Specialised Technology with Canine Workers

Thesis

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Animal-Computer Interaction: Designing Specialised Technology with Canine Workers

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Dedicated to Kathleen

Abstract

This thesis reports on research underpinning the design of a canine-centred dog-to-human communication technology, specifically an emergency alarm system that enables trained assistance dogs to call for help on behalf of their owners. Thousands of vulnerable people worldwide living with conditions such as epilepsy, diabetes or limited mobility, rely on assistance dogs to help them in their daily lives. When, for various reason, the human becomes incapacitated, such as when they are experiencing an epileptic seizure, have fallen, or have gone into a hypoglycaemic coma, it is down to their dog to take action to resolve the situation.

Interactive technology can provide an assistance dog with the means to raise the alarm and summon help, but in order to enable them to independently and successfully engage with an alarm, it is critical that they are able to make sense of when and how to use the device to increase their chances of successful interaction. Thus, the research presented here aimed to understand the factors that might influence the dog's ability to successfully interact with the system we undertook to design. Our initial design was informed by various biological, cognitive, and ergonomic considerations of dogs. We then elicited specific requirements for a canine emergency communication system by observing training practices to learn how trainers communicate with the dogs; interviewing human-dog partnerships to understand their needs; and engaged in rapid prototyping sessions with the dogs to identify their preferences. Using these requirements, 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. This led to the practical observation that for many assistance dogs, using an interface that allows them to bite an attachment with their mouth and tug it until it detaches was easy for them to learn to use. 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 and that 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.

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List of Publications

The work presented in this thesis has led to the following publications, in chronological order:

Robinson, Charlotte; Mancini, Clara; van der Linden, Janet; Guest, Claire and Harris, Rob (2014). *Canine-centered interface design: supporting the work of diabetes alert dogs*. In: ACM CHI Conference on Human Factors in Computing Systems, 26 April - 01 May 2014, Toronto, Canada, ACM.

Robinson, Charlotte; Mancini, Clara; van der Linden, Janet; Guest, Claire and Harris, Rob (2014). *Empowering assistance dogs: an alarm interface for canine use*. In: ISAWEL'14 Intelligent Systems for Animal Welfare, 4 April 2014, London.

Robinson, Charlotte (2014). *Designing specialized technology to aid assistance dogs*. In: Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing: Adjunct Publication, ACM, pp. 343–348.

Robinson, Charlotte; Mancini, Clara; van der Linden, Janet; Swanson, Lydia and Guest, Claire (2014). *Exploring the use of personas for designing with dogs*. In: ACI 2014: Pushing Boundaries Beyond 'Human', 27 October 2014, Helsinki.

Robinson, Charlotte; Mancini, Clara; van der Linden, Janet; Guest, Claire and Swanson, Lydia (2015). *Exploring Assistive Technology for Assistance Dog Owners in Emergency Situations*. In: PETRA '15: Proceedings of the 8th ACM International Conference on PErvasive Technologies Related to Assistive Environments, ACM New York, NY, USA , article no. 92.

Robinson, Charlotte; Mancini, Clara; van der Linden, Janet; Guest, Claire; Swanson, Lydia; Marsden, Helen; Valencia, Jose and Aengenheister, Brendan (2015). *Designing an Emergency*

Communication System for Human and Assistance Dog Partnerships. In: ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp 2015), ACM pp. 337–347.

Some ideas and figures have been presented in these previous publications. The findings discussed in Chapters 4, 5, and 6 are partially published in *Canine-centered interface design: supporting the work of diabetes alert dogs* (2014). The findings of the study discussed in Chapter 7 are partially published in *Designing an Emergency Communication System for Human and Assistance Dog Partnerships* (2015).

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Introduction

The Intersection of Animals and Technology

Animals are deeply entangled with humans. They are our companions, our food sources, and our co-workers. As human culture and practices become progressively computerised, animals increasingly come into contact with technology. Indeed, historically and presently, many animals interact directly with technological artefacts; in doing so, they become *users* in their own right. Human-Computer Interaction (HCI) regards users as those who engage with technology, where the interaction is shaped by a distinct set of needs resulting from their cognitive, cultural, and physical background (Dix, 2009). However, in recent years, within the emerging field of Animal-Computer Interaction (ACI), designers of technology are acknowledging that non-human users also exist, and are setting out to develop technology specifically for non-human animals. ACI aims to place the requirements of animal users at the centre of the design process, to design technologies that can support both animals and human-animal relationships (Mancini, 2011). Applications of ACI can support animal welfare and caretaking (Wirman, 2014; French et al., 2015), animal-human relationships (Resner, 2001; Cheok et al., 2011), and increasingly, the activities of working animals (Ferworn et al., 2007, Jackson et al., 2013; Mancini et al., 2016); usually dogs, as they are especially prevalent in human society as workers, (Coppinger and Schneider, 1995). However, ACI designers must deal with considerable challenges that may arise when designing for non-human species due to interspecies differences (Resner, 2001; Ritvo and Allison, 2014), which make it particularly difficult to understand and meet user requirements. Thus, this work is concerned not only with what interactive technology should be like to best support canine users, but also with how the methodological challenges arising from designing for dogs should be addressed.

This work, then, positions itself at the intersection of interaction design and animal studies, whereby an understanding of a particular animal species and an understanding of established practice for designing new technology for specific user groups is required to produce informed designs. It takes a user-centred design approach, specifically drawing from subset areas of inclusive design, assistive technology design, and child-computer interaction, all areas that look at how to design for users that may have differing abilities than that of the design practitioners creating the technology. It also takes into consideration existing work specifically in the field of ACI, which in turn may or may not have drawn from the aforementioned areas. By taking a UCD approach to designing for non-human animal users, this work addresses the question of what participation looks like when our users are non-human. Past work has identified application of well-established ladders of participation (Arnstein, 1969; Hart, 1997) as it applies to canine users (Hirskyj-Douglas et al., 2015).

While ACI encapsulates a growing body of work with its own methods becoming fine-tuned, it is still a young field and has many open questions and outstanding issues. Each different animal species presents their own unique challenges, and the purpose of the technology and interaction varies as well. This work specifically looks not only at how to engage animal users effectively, but also how to leverage the human-dog relationship in real-world applications that can be beneficial to both the canine and human users. This work resulted in a novel form of interaction for a specific problem, that is, a dog being able to knowingly, intentionally activate a device that calls for help in an emergency situation. Previous work in this area was very limited and mostly confined to wearables.

1.1 Technology and the Modern Dog

When we consider, broadly, dogs as users of computerised technology, we see that technology is in fact already often integrated into the life of many modern dogs. This is likely a reflection of the integration of technology into the lives of their modern human owners and handlers. For example, today's pet dog may be monitored while his owner is at work by dog web-cams[1]; his dog walker may add photos of his daily afternoon dog walks in real-time to Twitter or Instagram, and, in the United Kingdom, he is legally required to be injected with a permanent microchip under his skin[2]. His owners may fit his collar or harness with wearable GPS devices or pet cameras in order to monitor his fitness or whereabouts[3,4]. When he's left alone at his house, the dog may be fed by a programmable food dispenser[5] and left to interact with computerized toys[6], and such food dispensers or toys may even be controlled remotely in real-time from his owner's phone.

Figure 1.1. The modern dog owner may employ various technology in managing their dog's life L-R: two-way pet camera, dog fitness collar and phone app, and smart-phone controlled food bowls.

Clearly, dogs are already using technological interfaces and having their lives shaped in part from the existing technological landscape. This influence is not just restricted to pet dogs, but extends to working dogs as well. Many working dogs (such as search and rescue dogs, police dogs, drug sniffing dogs, and assistance dogs) have jobs that greatly enhance or even save human lives.

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[1] Dozens of remote pet cams available on market at time of writing, such as the Clever Dog Smart Camera™; the Motorola HD Pet Cam™; the Petcube Play™, and the Petzi Treat Cam™. See Appendix A for extended list.

[2] Law effective in UK from 2016: https://www.gov.uk/government/news/compulsory-dog-microchipping-comes-into-effect

[3] FitBark™ and dozens of other wearable telemetric or GPS collar devices available on market at time of writing, see Appendix A for extended list.

[4] Many cameras designed for dogs to wear on their collar, or harnesses compatible with popular action cameras like GoPros, are available on the market at time of writing. See Appendix A for extended list.

[5] Numerous programmable or remotely-controlled food bowls are available on the market at the time of writing. See Appendix A for extended list.

[6] Numerous interactive computerized pet toys are available on the market at time of writing. See Appendix A for extended list.

Increasingly, there is an interest in leveraging technology for these working dogs' care and support as well. In particular, there has been a growing interest in supporting assistance dogs, as they are instrumental in the daily support of many vulnerable individuals. Assistance dogs carry out tasks for their owners that their handlers cannot carry out themselves (Winkle et al., 2012). Guide dogs see for their handler[7]; hearing dogs hear for their handler[8]; mobility service dogs help their handlers with daily physical tasks[9]; and medical alert dogs warn their handler of oncoming medical emergencies[10], such as seizures, or episodes of dangerously low blood sugar. Despite an ever-increasing amount of assistive and home technologies available to vulnerable individuals, assistance dogs are actually growing in demand; national waitlists often stretch years for a certified dog and there are thousands of assistance dogs worldwide[11,12]. This is because thousands of people choose to partner with an assistance dog instead of, or in addition to, these assistive technologies. Indeed, assistance dogs themselves have been referred to by occupational therapists as "assistive technologies" (Zapf, 1998). Aside from offering practical help, these dogs can offer emotional and social health benefits that technologies do not offer. For example, dogs can act as catalysts for human social interactions. In general, the mutually interdependent relationship between a person and their assistance dog involves attachment and caregiving, and may provide significant social, functional, and psychological benefits for the human (Winkle et al., 2012). In addition to the practical benefits they provide, assistance dogs provide owners with an increased sense of social integration, substantially reducing the tendency of able-bodied people to ignore the impaired individual (Eddy, 1988) and thus have a major positive impact on the lives of their

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[7]International Guide Dogs Federation, http://www.igdf.org.uk/about-us/facts-and-figures/history-of-guide-dogs/

[8]Hearing Dogs for Deaf, https://www.hearingdogs.org.uk/

[10]Assistance Dogs International, http://www.assistancedogsinternational.org/about-us/types-of-assistance-dogs/service-dog/

[11]Medical Detection Dogs, https://www.medicaldetectiondogs.org.uk/about-us/medical-alert-assistance-dogs/

[12]For some examples of waitlist times, http://www.assistancedogs.org.au/pages/about-us.html, http://www.canineassistants.org/faq.html

owners (Allen and Blascovich, 1996; Rintala, 2008). Due to the nature of their work and close relationship with their humans, these assistance dogs often interface directly with human technologies that have not been designed with the animal in mind. For example, mobility service dogs learn how to execute tasks such as opening doors, loading laundry machines, filling shopping trolleys, and pressing buttons to operate things like elevators or crosswalk lights (Mancini et al., 2016). In some cases, assistance dogs are even trained to push buttons on a phone so that they can call for help if necessary. But assistance dogs perform such tasks at a deficit because their own physical capabilities are very different from those of the human users that these tools were originally designed for. In this work, we were thus interested in identifying challenges that assistance dogs encounter, and addressing these challenges via technological intervention. As we will discuss in later chapters, some of the challenges that were identified through this work were related to emergency situations that may occur when an assistance dog and their owner are alone.

1.2 Enabling Assistance Dogs in Emergencies

Having an assistance dog trained to respond to emergencies can significantly reduce or eliminate some individuals' emergencies associated with their condition (Strong et al., 1999, Rooney et al., 2013). However, some individuals' conditions can be so brittle that even the support of an assistance dog will not always prevent emergencies that require outside intervention. When a person experiences an emergency, assistance dogs, who are usually with their humans 24-7, are likely to be present when the emergency occurs. However, assistance dogs are usually limited in their ability to help if there are no other humans nearby, leaving the human in danger and the dog distressed. As an example of how such an emergency may arise, we can consider a type of medical alert assistance dog that faces these problems more than others: Diabetes Alert Dogs (DADs).

Worldwide, an estimated 371 million people currently suffer from diabetes, a serious disorder in sugar metabolism (Shaw, 2010). 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 (van Belle, 2011), they are greatly feared by diabetes patients. Existing blood glucose monitoring devices (BGMs), which are worn full-time on the body to monitor glucose levels, may be inaccurate and are often not a practical stand-alone solution to prevent day to day hypoglycaemic attacks for many diabetics (Joseph et al., 2009). Due to their extraordinary olfactory capabilities, DADs are capable of not only detecting changes in their owners' blood sugar levels, but also capable of promptly alerting the owner to those changes faster and more accurately than existing devices, enabling their owners to address the problem by ingesting food or other measures. In this way DADs can significantly contribute to their owners' quality of life and safety (Rooney et al., 2013). However, some hypoglycaemic attacks can be so sudden that the owner falls into a coma before being able to act upon their dog's alert. If no other humans are around, the dog is then unable to assist further, left alone helpless with the unconscious person. But what if technology existed that empowered the dog to take action in such situations?

Consider the experience of the following persona, "Paula", and her DAD "Buddy":

Paula has Type 1 diabetes and lives in constant fear of hypoglycaemia. Like approximately 25% of diabetic patients (Bilous and Donnelly, 2010), she has developed 'unawareness' over the years and cannot tell when she is becoming hypoglycaemic, that is, when her blood sugar levels are dropping dangerously. Because of how quickly her levels can drop, and her inability to react once they start, many continuous blood glucose-monitoring systems have failed to help Paula prevent medical emergencies. However, Paula's dog, Buddy, is trained to detect and alert to hypoglycaemia in Paula by nudging her persistently. Buddy seems to be able to detect a problem faster than the wearable systems Paula has tried, and what's more, he is harder for her to ignore than the machine, since instead of beeping, he nudges her, barks, and generally causes a fuss until she tests her blood sugar levels and takes action. Many times, Buddy's alerts have prevented Paula from undergoing a severe hypoglycaemic attack, allowing her to restore her blood sugar levels with food *or drink before they became too low. Paula feels lucky to have an alert dog by her side; knowing her dog will alert her before any machine would be able to do so has dramatically improved her quality of life by giving her peace of mind. However, there are still situations where even Buddy has not been able to prevent her from falling into a hypoglycaemic coma.*

Consider the following contrasting scenarios of a typical hypoglycaemic attack and their respective outcomes:

Scenario A
One day, Paula is home alone with Buddy. Buddy smells Paula's blood sugar levels dropping and gives the alert by persistently nudging Paula. However, Paula's levels have dropped so quickly that she has already become disoriented and unaware of her surroundings. Buddy can tell that she is deteriorating and continues nudging and pawing at Paula. Buddy escalates the alert by bringing Paula her blood testing kit, as he is trained to do when his initial persistent nudging does not work. When Buddy brings the blood test kit to Paula, it is a usually a clear sign to her that Buddy thinks there is a problem. However, Paula has already slipped into a coma. Buddy paces back and forth, distressed that Paula 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 unconscious owner's side.

Figure 1.2. Buddy witnesses Paula fall unconscious due to hypoglycaemia, unable to help the situation.

Scenario B
One day, Paula is home alone with Buddy. Buddy smells Paula's blood sugar levels dropping and gives the alert by persistently nudging Paula. However, Paula's levels have dropped so quickly that she has already become disoriented and unaware of her surroundings. Buddy can tell that she is deteriorating and continues nudging and pawing at Paula. Buddy escalates the alert by bringing Paula her blood testing kit, as he is trained to do when his persistent nudging does not work. However, Paula has already slipped into a coma. As the next step when Paula passes out, Buddy knows how to use his special alarm system to remotely contact Paula's spouse and other

friends or family. He takes action and triggers the alarm. Unless overridden within a few seconds, the system is preconfigured to send an SMS to relevant people, who are prompted then to call Paula to check the situation. If she does not answer their calls, they can call emergency services. If no friends or family return the alarm's original call within a couple of minutes, the system escalates to calling emergency services directly, providing GPS coordinates of Paula's location. Buddy paces worriedly for a few minutes, but then help arrives. Paula's chances of brain or heart damage, or even death, have thus dramatically decreased and Buddy has been spared hours of distress.

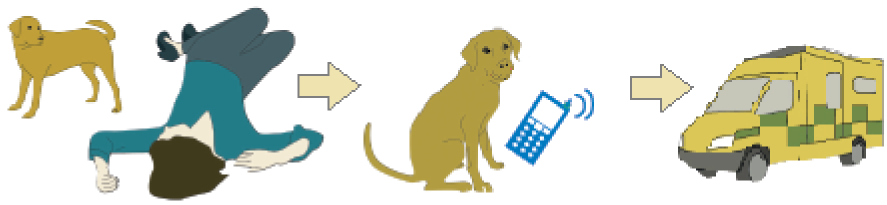

Figure 1.3. Buddy witnesses Paula fall unconscious from hypoglycaemia; he triggers an emergency alarm system to call for help; help arrives in time to save Paula from the risk of serious medical consequences.

The above scenario aims to illustrate the need for a canine alarm system, but what should this alarm be like, and how would one go about designing such a system?

1.3 Research Questions

The above scenario requires that the alarm used by Buddy is designed to be accessible to dogs. Such an implication raises the following research questions:

RQ1) How should an alarm be designed to be usable by assistance dogs and provide them with the best possible support for the critical task of dealing with an emergency on behalf of their assisted human? In particular, what design features and interaction mechanisms might help dog users learn how to effectively engage with the technology at the right time? Can HCI design principles and goals commonly referred to when designing interactive systems for human users help design for canine users?

RQ2) How should interaction designers proceed with designing technology for a user of a different species? In particular, given interspecies differences and communication barriers between canine users and human designers, how can the latter ensure that what they design is indeed usable by the former? Can we draw upon existing HCI methodologies, such as user-centred and participatory design, to facilitate the design process and achieve specific design goals? Specifically, can methods leveraged when designing for users with specific abilities, such as those involved with inclusive design, ability-based design, assistive design, and child-computer interaction apply when working with canine users?

The doctoral research presented here addressed these questions, and by investigating a particular ACI application, sought both to support a specific group of canine users and to contribute to the development of an approach to designing for and with canine users (which might be extended to designing for and with some other species), thus contributing to the development of ACI as a discipline.

The remainder of this dissertation discusses the steps taken to achieve these aims. In particular, Chapter 2 provides background on the past and present relationship between animals, humans and technology, exploring what work has been done in the broader field of ACI; and more specifically with dogs; the chapter also provides a literature review about dogs as a species to better understand the user we were designing for. Chapter 3 provides an overview of and explains the motivation behind the methodological choices made during this research. Chapters 4, 5, 6, 7 and 8 describe each consecutive research study that was conducted, presenting the findings and a brief discussion of how the result of the study informed the successive study. Chapter 9 provides a discussion of the research as a whole and presents the specific design contributions and methodological contributions of this work. Finally, Chapter 10 draws a brief conclusion from this research journey.

2

Literature Review

2.1 Introduction

In this chapter we provide background on variety of research areas to situate this work within the existing ACI landscape. Firstly, we provide an overview of different kinds of interactions between animals and technology. We examine the use of tools by wild and domesticated animals, showing that both wild and domesticated animals are capable of making use of tools (and thus technologies) for a purpose. Having thus identified non-human animals as potential users of technologies, we then review a range of technological devices that have been specifically designed for animals to use. We then discuss the methodological approaches taken to develop some of these existing technologies, and the extent to which these approaches take into account the sensorial, physical and cognitive characteristics of the target species, as well as the role of animal users within the design process. Subsequently, in order to begin to understand assistance dogs as our target users in this research, we then delve into dog biology, cognition, and social behaviour, highlighting the special relationship that dogs have developed with humans through co-evolution.

2.1.1 Animals and Technology

Anthropologists believe that animals have always been integral to human society and central to human thought (Manning 2002; Shanklin, 1985). Recent discourse on these relationships has seen a re-evaluation of many human-animal relationships, with the human-animal relationship now considered to be extremely dynamic and complex rather than a simple case of human superiority and domination (Kirksey and Helmreich, 2010). Within this modern line of thought is the concept that humans and animals are actors, playing both active and reactive roles within their interactions with each other (Haraway, 2008). Indeed, much literature implies that, as long as animals and humans have co-existed, they have been shaping each other and acting on one another (Schleidt, 2003). Thus, whether technology is basic or at the forefront of technological advancement, since technology in some form pervades human society, it stands to reason that technology is bound to influence animals and their relationship with humans.

2.1.2 Animal Tool Use and Object Manipulation

Some animals have been found to be able to use technology to carry out specific tasks they want to accomplish, for example using a stick to harvest termites out of a tree, or using a sponge to search shells on the seafloor (Boesch and Boesch, 1990; Smolker et al., 1997). Indeed, while originally tool use was thought to be unique to humans, it has now been long established that many non-human animals use tools (Beck, 1980); indeed, some non-human animals also manufacture tools as well as showing an ability to use them.) Tool use and tool manufacture are shown to be widespread across three phyla and seven classes of the animal kingdom (Bentley-Condit, 2010). One accepted definition of tool use is "the use of physical objects other than the animal's own body or appendages as a means to extend the physical influence realised by the animal". By this definition, tool use by both wild and domesticated animal populations has been documented repeatedly, as we will discuss in the next section.

Tool Use in the Wild

A well-known example of tool use by animals in the wild is that of chimpanzees using sticks to collect termites (Goodall, 1964). To do this, chimps take a stick, poke it down an opening in a tree, and pull it back out to lick off the termites that have accumulated on the stick. Doing this requires knowledge about where to poke, what kind of stick is more suitable, and how to manoeuvre the stick just right to get the best results. These are learned behaviours, taught from elder to younger chimps, and vary across different chimp populations (Ch and Boesch, 1990; Whiten et al., 2005). In addition to using sticks for termite collection, chimps also use sticks to disable bees guarding bee-nests; in combination with leaves to scoop honey; and using rocks to open nuts; they also fashion sponges out of leaves and moss to drink water or to use as a grooming aid (Fay, 1994; McGrew, 1973). Similarly, the bottlenose dolphin community in Shark Bay, Australia, use conical sponges as tools while foraging (Krützen, 2005). The dolphins break off a piece of sponge from the ocean floor and wear it over their rostrum (nose), to protect it while they forage for food on the seafloor. Researchers observed dolphins spending a considerable amount of time searching for a sponge with the right shape and then use the same sponge for some time (Smolker et al., 1997). These Shark Bay dolphins have also been observed carrying conch shells to scoop fish from the seafloor substrate (Allen et al., 2011). Elephants are another species that are known to use tools in the wild. They use branches to swat flies or as scratchers, and have been known to spend considerable time finding the right size and shape of branch to suit their needs, as well as shaping existing branches with their trunks. They have also been observed to dig water holes, then fashion ripped bark from trees into a ball and cover the hole with sand to avoid evaporation, then later return to drink the "stored" water (Hart, 2001). Although many species of birds have been shown to use tools, New Caledonian crows are especially worth note, as they have been observed to make the most complex tools of any non-human animal. The tools that they make are usually made to catch insects. In the wild, crows will choose a twig and remove parts of it to obtain a sculpted, sharpened tool allowing them to access food that they otherwise could not reach (Hunt, 1996). These examples (and others) show that across different continents and species, wild, non-human animals are able to physically manipulate objects found in their environments to accomplish a variety of tasks. These tasks are tasks that the animal themselves perform intentionally and spontaneously (that is, with no training or coercion).

Animals Repurposing Human Objects for Use As Tools

In addition to using tools in the wild, some animals have demonstrated an ability to re-purpose human objects in their environment to use as tools. For example, captive male elephants have been observed to move boxes to reach food that has been hung out of reach (Chevalier-Skolnikoff, 1993). Without any direction or training, these captive elephants were able to move the boxes to achieve their goal of reaching out of reach food, thus integrating human artefacts into their own environment and practices. Similarly, crows in captivity have been shown to manipulate foreign objects (that they have never come into contact with before) into tools. For example, they have been observed fashioning garden wire into hook-like shapes in order to access out-of-reach food (Hunt, 1996). This ability to fashion new tools to solve a problem never before encountered demonstrates an awareness of the potential for one object to be fashioned into another more useful one.

In addition to these examples of various wild animal species using tools within human environments, some domesticated animals, primarily domesticated dogs, have also anecdotally interacted with objects, without human direction, in a manner to use them as tools Although spontaneous tool use has not been observed in the wild by either dogs or wolves, domesticated dogs have shown the ability to manipulate objects in their environment. Perhaps unsurprisingly, given that dogs live in human environments, there are many examples of dogs using human objects to accomplish a task. A quick browse of YouTube will show cameras capturing a variety of scenes taking place in the absence of humans: a dog moving a chair close enough to the kitchen counter to use as a step-ladder; a dog using a small boat to get to a ball across a pool without getting wet; or even a dog riding a bus unsupervised to get to a park. These examples, together with others, imply that some dogs are capable of using objects in their environment to achieve something they desire, whether it is stealing food off a counter or getting to a destination such as a park much more quickly than they could do by just walking.

The above discussion demonstrates that other animals as well as humans are capable of using-and willing to use- tools that are at their disposal to accomplish a task of their own choosing. This may suggest that non-human animals are all the more likely to be able to use tools for activities that are relevant to them- if such tools were to be provided for them to use.

2.2 Technology to Support Animal Caretaking

2.2.1 Devices to Manage Animals in Human Environments

Areas of application in which technology has been specifically targeted to animals for several decades include animal studies and husbandry, where there has been a surge of purpose-built technologies for the management, tracking, or caregiving of individual animals or animal populations.

2.2.2 Automated Farming

In recent years, the management of livestock has seen widespread technological advances (Loyon, 2016). The automation of gate control, feeding, stall cleaning, and milking has become common-place (Voulodimos et al., 2010). Precision Livestock Farming (PLF) is the use of advanced technologies to “optimise the contribution of each animal” (Wathes et al., 2008). PLF uses technology to monitor and improve the productivity of each individual animal, something that is not possible on a large-scale farm without the use of technology (Berkmans et al., 2006). On some modern farms, virtually all aspects of the farming process involve technology, from identification and tracking of each individual animal to feeding optimization algorithms to control automated feeding machine systems. While such technologies are not the focus of this thesis, they do serve as an indication of how widespread animal technologies have become, given the sheer scale of the livestock farming industry globally.

2.2.3 Technology-Supported Caregiving of Domesticated Pets

In recent years, there has also been an increase in the availability of technologies designed for domesticated pets, also known as companion animals. Many of these technologies are designed for to support the care and welfare of pets, or to support pet owner interaction with their pets. For example, toys such as the iFetch Interactive Ball Launcher Dog Toy[1], was designed to provide for many dogs caregiving tasks while the owner is otherwise occupied. The product invites owners to "play fetch for hours while you do some cooking, go for a walk, or do some reading. iFetch actually trains dogs to play fetch without humans. Just plug it in, drop in the ball, and play!"[1]. Another device, the Scat Mat[2], is a clear mat that emits a pulse to keep pets out of certain areas of the home so that "pets can learn quickly which areas of your house they're not allowed to go". The mat produces a "startling, unpleasant pulse" that is intended to make the pet form a negative association with certain areas without forming any negative associations with the owners themselves, effectively automating the teaching or disciplining by the owner. Pintofeed[3] and other automated feed systems are pet-feeders that are controlled by a phone app that allows owners to program automatic feeding schedules and notifies them how much an animal has ingested. Additionally, the Litter-Robot[4] is advertised as a litter management system "for the cat owner that never wants to scoop a litter box again".

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[1]The iFetch Interactive Ball Launcher Dog Toy™', http://www.goifetch.com

[2]ScatMat™, at time of publication available to purchase at Petco and Amazon

[3]Pinto-Feed™, http://www.pintofeed.de/

[4]Litter Robot™, https://www.litter-robot.com/

Whether such automation, which serves to automate and streamline tasks that previously a pet owner would have had to do themselves, such as feed or play with their pets, is a positive or negative addition has been questioned. In particular, Paladanius et al. (2011) noticed that generally pet owners do want to spend time with their pets and care for them, thus the technology developed should support these interactions rather than attempt to automate such practices. However, in the case of gadgets such as Shru[5], a robotic cat toy that rolls on the ground and emits noises, owners may have their attention drawn to their pet or engage more with their pet than they would if the toy were not in the households.

2.2.4 Pet Tracking Devices

At the time of this thesis publication, several pet-tracking wearable devices and systems are available on the market. At the time of writing, some of these include: Voyce[6], Whistle[7], Dog Tracker Plus[8], WUF[9], Tractive[10], Garmin[11], Nuzzle[12], PawTrax[13], and Retrieva[14]. These technologies

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[5]Shru, , http://getshru.com/

[6]Voyce™, http://voyce.com/

[7]Whistle™, http://www.pettracker.com/

[8]Dog Tracker Plus™, http://store.dogtrackerplus.co.uk/

[9]WUF™,https://www.getwuf.com/

[10]Tractive™, https://tractive.com/en/

[11]Garmin™, http://www8.garmin.com/dogs/

[12]Nuzzle™, http://hellonuzzle.com/

[13]PawTrax™, http://www.pawtrax.co.uk/

[14]Retrieva™,http://www.retrievatracking.com/

are advertised for both pet dogs and cats, as well as working dogs that travel over a large range of outdoor terrains. The sheer amount of available systems reflects the popularity of pet owners' desire to be able to monitor their pet, either in routine practices or in emergency situations, such as when a pet may be lost, stolen, or injured. Some work has been done to investigate the tracking practices and how tracking technology effects human-dog relationships (Mancini et al., 2012).

The pet technologies mentioned above all fall into categories of either integrated “smart collars” or separate devices that can be attached to a collar or harness. Most sync with a phone app to allow real-time tracking and data visualisations. Such devices are potentially important to pet safety and welfare; most allow the pet owner to set safe zones for their pet. Once a pet owner has configured what physical space a pet is safe to roam, if the pet crosses the boundary of one of these “virtual fences”, the system triggers a real-time alarm providing a pet location visualisation. Other devices have LEDs built in that will automatically light up in dark conditions and can be made to flash if the owners are concerned that the dog may be lost. Some of these devices, such as WÜF, also have integrated ultrasound and vibration commands intended to assist with training, allowing the owner to communicate with the dog via acoustic or haptic signals, or even speak to the dog remotely via micro speakers.

Other collars, such as Nuzzle, Voyce and PawTrax, along with activity tracking, will monitor pet vitals such as temperature, heart and respiratory rate as well as rest patterns, posture patterns, activity and calories burnt. The ability for owners to track health data and store veterinary information embedded on a pet have significant implications for the pet's health and well-being. For example, even if a pet becomes separated from their owners and a new caretaker is not able to contact the owner, the new caretaker and veterinarian would be able to know if the animal was on any medications or has had any health issues previously. On the other hand, these technologies are not without potential negative impact as well: recent work has indicated that intensive monitoring by some of these devices has little scientific justification, and even has the potential to hurt animal welfare, undermine human-animal bonds, and create human-human conflicts (Lawson et al., 2015).

2.2.5 Technology to Support Animal-Human Communication

Pet tracking devices, such as the ones discussed above, can be used to manage aspects of keeping and providing care for animals by automating tasks that would otherwise have to be executed manually by a human (e.g. feeding), or that would not otherwise be possible (e.g. tracking), thus making the care of the animal easier or more efficient in some way. Though such technologies may potentially facilitate interaction between humans and animals in some situations (Mancini et al., 2012), they have not been designed to allow the animal using the system to *intentionally* communicate with their human handler. By contrast, other animal-related technology is designed specifically to support the communication between two species; either making communication easier, or enabling communication that would not be possible without technological intervention.

Animal-to-Human Communication

Researchers have explored communication between humans and primates for decades. Rumbaugh (1977) developed Yerkish, a computer-mediated symbolic language developed to enable great apes to communicate with humans. The system consisted of a keyboard with sets of lexigraphical symbols that allowed a gorilla, Lana, to create grammatically correct sentences. It even included an ‘enter’ button to allow Lana to mark the end of her sentence and input to the system, and an output area where the system could communicate back to Lana. The basis for creating a computer mediated communication system was to reduce ambiguity interpreting Lana’s communication and to enable automatic recording off all conversations. However, the project was criticised for interfering with the social use of language, as Lana was no longer interfacing with the trainers that she had formed bonds with.

Another project that sought to computer-mediate human and primate communication is the Koko Project[15]. Apple adapted a Macintosh II to allow Koko, a Western Lowland gorilla, to communicate better with humans. The system had 24 icons on a touch screen, which Koko could press, and the system would then create human speech based on her input, effectively giving Koko a “voice”.

More recently, researchers at Bonobo Hope Great Ape Trust Sanctuary have developed a tablet app that allows humans to communicate with bonobos who are living in the sanctuary, using the same simple lexigrams that the scientists at the sanctuary have been using for years (Schweller 2012). The interface featured a touchscreen computer keyboard and an app to translate automatically between the humans and bonobos. The project aimed to allow bonobos to experiment with the app themselves, using it to do things like operate vending machines, open doors, watch movies and control robots.

Two-way communication keyboards have also been developed for dolphins. An underwater keyboard interface was created for dolphins to use to communicate with humans by pressing keys with their snouts. Each key was associated with a specific outcome, so the dolphin could learn to request food, objects, or physical affection by pressing on the corresponding key (Kohlsdorf et al., 2013).

All systems described in this section feature an interface that uses symbols whose meaning the animals learn through training in order to communicate with humans. However, they only provide a relatively simple system of communication between animals and humans based on established human language conventions, and are not designed to enable humans to in turn speak the language of the animals in question.

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15 http://www.koko.org/

Human-to-Animal communication

While communication systems like those described above have been developed to enable animals to better communicate to humans, other technology has been developed to enable humans to better communicate to animals primarily, to allow humans to better communicate with working dogs. Due to the importance and nature of the work that working dogs may carry out, there is a need for this communication to work well in real-time as the human and dog are working together to accomplish a task, for example, while carrying out search and rescue or explosive detection work.

Early systems in this application area aimed simply to allow the dog handler to remotely “control” their dog by sending vibrotactile or auditory stimuli to the wearable device worn by the dog (Brit et al., 2006; Byrne et al., 2007; Ferworn et al., 2007; Auburn University 2010). Additionally, a more recent project, COCHISE, has sought to also create an "augmented" assistance dog; this system aims to support speech-challenged assistance dog owners with disabilities to communicate with their assistance dog by using vibrotactile stimuli (Rybarczyket et al., 2013; Lemasson, 2014). Such a system could potentially allow disabled handlers to instruct or guide their dogs that would not have been able to otherwise. However, in this work, it was found that in situations where the dog ignored the owners command, and the system delivered a vibro-tactile stimulus to get the dogs attention, the dogs sometimes displayed stress responses (indicating discomfort). Thus, further work needs to take careful consideration of the welfare and user experience of dogs that are expected to use wearable systems where they cannot control the stimuli. For much of this existing work, however, the focus is on the dog’s ability to perform tasks while wearing such devices, rather than the dog’s experience of the technology. Overall, 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.

Two Way Communication

In contrast to human-to-dog, one-way "control" systems, the FIDO (Facilitating Interactions for Dogs with Occupations)[16] project aims to support communication between dogs and their handlers, that is, to support two-way communication back and forth between both handler and dog. The project has developed a wearable harness device for working dogs, which allows the dog to remotely signal to their handlers (Jackson et al., 2013). As in the case of the devices described above, the dog wears a vest, but in this case, there are parts of the vest that the dog can interact with to communicate with his handlers. For example, the vest can be fitted with different types of attachments such as a biteable or tug-able attachment that, when the dog bites or tugs it, sends a signal back to the human. An example of how this can be used is described by the authors (Jackson et al. 2013) in the context of search and rescue practices, whereby the dog enters terrain that their human handler cannot navigate. When the dog comes to an injured person, they can bite the attachment on one side of their vest to communicate back that the person is unconscious, or on the other side if the person is awake. The handler can then remotely ask the dog to come back or to stay with the person. This is just one scenario of many where a two-way 'conversation' between the working dog and its handler can be facilitated by the system. This work has shown that dogs can effectively and remotely communicate in real-time with their handlers via a wearable system. However, it has not explored alternatives to a wearable system, which could be necessary in certain contexts (since due to welfare and logistical reasons, working dogs do not wear vests/devices 24-7, but rather in shorter periods).

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[16] FIDO, http://fido.gatech.edu/

2.2.6 Systems that Facilitate Human-Animal Relationships

Yet another area where technology is developed specifically for animal users is those technologies that are intended to facilitate human-animal relationships. These systems enable novel multi-species interactions by introducing a technology that both species interact with at the same time, thus fostering bonds and between animal and humans.

A number of systems have been designed to allow pet owners to play with pets remotely. The first of such systems was Rover@Home (Resner, 2000). Rover@Home was a form of internet-mediated remote dog training, and consisted of two interfaces: a human interface and a dog interface. The human interface used an internet-enabled computer to give treats to and communicate verbally with the dog. The dog received audio commands from the human via speakers and food rewards via an electric dispenser. The system relied on a very popular training method called 'clicker training', whereby an animal is conditioned to get a food reward upon hearing a click, such that eventually the click itself becomes a marker for wanted behaviour. Even though the owner could be physically located miles away, through the system, he could produce a click that the dog would hear in real time. Since this initial project, many "doggie Skype" systems have been developed to allow dog owners to observe, speak to, and deposit treats to their dog while they are not at home (see Appendix A for an extended list of such devices). Another early system that allowed owners to remotely bond with their pets was a haptic wearable human interface called Poultry.Internet, an interactive system that allowed pet owners to stroke their pet chicken remotely through the internet via a small jacket worn by the chicken (Lee et al., 2006). The system transferred human contact on a physical dummy doll to the chicken via vibrotactile actuators embedded in the chicken's jacket, enabling real-time remote petting of the chicken. Another system, Feline Fun Park was an interactive cat entertainment system that allowed cat owners to remotely interact with their cats by moving objects such as toy mice and LED lights embedded in a 'cat condo'. There was no camera installed, however, so the pet owner could not actually see their cat's responses, but had to gauge these reactions by relying on sensor data installed in the cat's environment (Young et al., 2007).

Other systems developed early on in ACI's history allowed co-located humans and pets to play or bond via a technologically mediated interaction. Metazoa Ludens was a gaming system developed to involve hamsters in a mixed reality game with humans (Tan et al., 2008). The game used food to entice the hamsters to chase after a tunnel that moved around in the game area. The hamster's movements were tracked with cameras and translated into the movements of an online avatar that the human player could see on their screen. The human player controlled the moving tunnel object through the game on the screen. Other systems have aimed to facilitate real-time co-located play between dogs and their owners. For example, Canine Amusement Training (CAT) involved both human and canine wearing sensors that tracked the movements of both while they attempted to go through different 'choreographies' guided by different projections on a play floor (Wingrave et al., 2010). In the game, the dog followed different cues such as 'stay' or 'come'. To challenge the players, distractions such as barking or doorbells were added.

The systems in this section illustrate a range of technological interactions devised for different purposes. Uses of technology vary from applications that notionally aim to improve animal welfare to systems that aim to optimise human management of animals. Many technologies have been developed for domesticated animals, especially companion and working dogs. However, there is still limited understanding of what tools working dogs may need in specific contexts, particularly when it comes to giving them control to accomplish individual tasks, particularly in critical situations. In the next section, we review methodologies that have so far been applied to develop technologies intended for animals.

2.3 Methodological Framework: Animal-Computer interaction

2.3.1 Designing for and with Animals

There has been a gradual change from designing technology that is simply applied onto animals, to designing technology that allows animals to take more active roles; from applying frameworks that rigorously account for the animals' specific characteristics, to borrowing methods that enable researchers to evaluate the technology from the animals' perspective. In recent years, Mancini (2011) proposed the unification of research efforts in this area and the systematic development of ACI as a discipline around specific research aims, one of which was to inform "a user-centred approach to the design of technology intended for animal use, by systematically exploring, adapting and evaluating theoretical and methodological frameworks and protocols derived from both HCI and animal science". This doctoral research directly contributes to the ACI discourse by addressing a particular gap in computer mediated animal-human communication, but also by contributing to the development of animal-centred design frameworks and methods that allow animal users to fully participate in the design process, specifically in the development of canine technology to support assistance dogs.

2.3.2 Existing Frameworks and Using Human-Computer Interaction to Inform ACI design

While ACI extends beyond the existing area of HCI, it faces some of HCI's same methodological issues related to understanding the users that technologies are designed for and meeting those users' needs. Here we discuss how ACI may borrow from HCI's body of work, in particular the discussions around *user-centred design*. In so doing, we also refer to the work of researchers who have worked with special human users, such as those with disabilities or children, as there are overlaps with ACI challenges. For example, the open ACI challenge of designing for users that are not able to verbally articulate their responses to a design, and may need to engage in the design process by other means.

A User-Centred Approach

In the last two decades of the twentieth century, HCI saw a shift in focus to not only studying and developing technical systems, but improving the usability of such systems, (Carroll, 1997) and this shift has continued in the forum of pervasive and ubiquitous computing in recent years. Thus, HCI has a large body of user-centred research to draw upon. Included in this body is research specifically designed for users with disabilities, older users, and child users, which may be relevant to designing for animal users.

One thing that characterises designs conducted as Animal-Computer Interaction from other instances of creating technology for animals is ACI's user-centred approach, which has led ACI researchers to explore the adaptation of user-centred design principles typically used in HCI design (such as iterative design, usability goals, design principles, and user involvement). User-centred design aims to optimise for the end user's particular wants and needs; with a preference towards adapting the technology towards these wants and needs, rather than presuming the user will adapt to the technology (Abras et al., 2004). One widely adapted methodological approach to user-centred design is Participatory Design (PD) (Schuler, 1993). PD is a diverse field, "drawing on fields such as user-centred design, graphic design, software engineering, architecture, public policy, psychology, anthropology, sociology, labour studies, communication studies, and political science, and from localized experiences in diverse national and cultural contexts" (Jacko, 2012). In accordance with user-centred design's focus on the user and their unique needs, PD attempts to engage all stakeholders in the design process (Gulliksen et al., 2003), which can enable users to represent their emotional, practical, cultural and physical needs. Participatory design techniques reflect design "as a social process, illustrating that the sphere of the design activity extends beyond the designer…The people who are commonly known as the 'users' are active participants in the design process and hence the boundary between ‘designer’ and ‘user’ becomes blurred.” (Luck, 2003). For human users, many participatory design methods have been established, and there are frameworks and taxonomies in place to categorise what level of participation a person might have in a design project. Now, with animal users being considered from a participatory perspective, ACI seeks to explore ways of allowing animals to take part in the development process as research participants and design contributors (Mancini, 2011). The forms that such participation might take are bound to be different from those of human participation and instead informed by the characteristics of specific animal users. In order to evaluate what different forms of participatory design can look like, we review recent shifts that have resulted in a focus on what a user can do rather than what they cannot, an approach that crosses boundaries across species.

Users: Incorporating an Ability-based Design Approach

Recent work designing for users with disabilities, the very young, or very old, has shifted from assistive technologies that build an intermediate system or adaptation to “fix” or correct what a user is perceived to be missing (such as blind users “missing” the sight that the interface expects for its users). Increasingly, we see a shift towards *ability based design*, which considers that all users have specific abilities that may fluctuate based on their specific background, physicality, or even environment (Wobbrock, 2011). Ability based design shifts the focus to creating systems that leverage the full-range of the users’ potential rather than compensating for their limitations (Wobbrock, 2011; Keates and Clarkson, 2003; Newell and Gregor, 2011; Clarkson, 2013). From this perspective, all people have varying degrees of ability, and different situations lead to different ability limitations, some long-term and some momentary. This is especially in line with ACI where we would like to view animals not as ‘impaired’ or ‘less able’ than humans, but rather distinct users with their own set of ergonomic and cognitive needs that may or may not fit with existing human models. The idea that all living creatures have certain abilities, that are not fixed but rather fluid based, is very relevant to ACI.

Gregor and Newell pointed out that techniques of user-centred design needed to be modified for older or less-abled users, such as finding and recruiting “representative users” specify exact characteristics and functionality of user groups, consider personalise-able and adaptive interfaces to be able to accommodate what the design process unearthed, and being aware that the abilities and characteristics of their users would change on different time scales. (Gregor and Newell, 2001) While user centred design grew out of a need to focus on the user and their needs, widely adapted user-centred methods were not sufficient, because they had been developed for user groups with relatively homogenous characteristics. More and more work is calling for methods that acknowledge dynamic and contextualised abilities (Wobbrock, 2015). Similarly, Benton talks about designing for “neurodiverse” children users of technology. Neurodiversity reframes conditions like dyslexia and autism spectrum disorders by re-focusing on their strengths. Reflecting this, a framework Diversity for Design was developed, providing guidance for designers working with neurodiverse children, directing designer’s attention to children’s strength while not disregarding support for their difficulties (Benton, 2014).

Approaches to challenges of non-verbal users

Research with non-verbal participants rarely focuses on this one element of their user profile; as being non-verbal can stem from a myriad of reasons, from ASD to quadriplegic, or temporary means, and can span the children to the elderly. Thus, much of this work focuses on the many issues and nuances of working with these different, and fluidly defined user groups, rather than isolating practical methods with which to draw feedback from a particular subset of non-verbal participants.

Cheverst argues that the requirements for a technological intervention for disabled users must come through considerations of details from case studies, and by understanding disability is not fixed; disability is a continuum rather than dichotomy (Cheverst et al., 2003). This approach uses combination of ethnographic studies, user centred design and evaluation, as well as the use of “cultural probes” with disabled and elderly participants, noting that they are following a recent trend towards qualitative, and particularly ethnographic methods of investigation, and nothing that ethnographic methods help to understand the context in which the systems are placed. This is compatible with the stance that disabilities and abilities are context and environment specific, fluid and that user requirements for these user groups may be best uncovered, elicited, or validated in real world settings. Many practitioners express the value of multiple methods, avoiding a one-size fits all approach, when working with children user groups with special needs (McNaney, 2013). Multiple literature identifies the following challenges of working with non-verbal children or special needs users: A lack of clear consensual definition of what special needs is, and the challenge of giving voice to those who cannot communicate effectively with the design team. This is a recurring theme of modularity (adaptability), i.e. ability to take a range of input devices especially (Lopes, 2001; Crabtree et al. 2003).

Similarly, researchers have identified that non-verbal users that are adults with high levels of cognitive ability present quite different challenges to those that are non-verbal children, or non-verbal adults with less cognitive ability. High cognitive ability, but lacking the capacity to speak, results in a communication challenge, but otherwise works well with other models as there are not additional barriers between the designers and the participants. As such, there is a focus on creating input systems that are compatible with the non-verbal abilities the user has (such as the ability to make other noises, gaze, etc.)

Multiple work has noted that the primary challenge of designing with non-verbal users is difficulty with speech based methods, not allowing for open-ended or a more ethnographic approach, because their ability to produce long, detailed answers or stories may be compromised depending on their other abilities. The others note that in an effort to attain rich data that is usual from ethnographic methods, they may use leading questions, however the validity and reliability of responses can be questionable if the users have a limited vocabulary. And, in order to support interviews with non-verbal users, scaffolded interviews can be used to include visual aids like cue cards and talking mats or tiles. They also note that due to the slower nature of using probes and taking care to reflect on the answers of the user throughout the interview, it would be more beneficial to split sessions up. Finally, they note that participants often know each other well over a period of long time and may understand each other's verbalisations or other communicating signals better than attendants or researchers, and thus a collective knowledge may be leveraged (Frauenberger et al., 2011; Carmien, 2005; Zisook and Patel 2002).

Approaches Leveraged from Child Computer Interaction

Recently, more and more, children are seen as co-designers; models such as Hart's ladder of participation aim to obtain as high a degree possible of participation for children. Child-Computer Interaction (CCI) defines the child user into roles of user, tester, informants, or design process (Druin, 2002). These roles are not necessarily different from the roles that adult users may take on, however the specific methods, context and challenges can be very different (Hart, 1992). While there are many common themes between child-computer interaction and ACI, there are also differences. While it may be tempting to directly lift certain methods from CCI, it is worth considering these differences before doing so. For example, much of the body of CCI literature is framed within the educational system, meaning that the child's educational environment are the focal point of the design. Most animals do not have years of rigorous, systematic education (a very notable exception being working dogs, and perhaps sport horses).

As Druin notes, in almost all early literature of the 1980s and 1970s in CCI, "The terminology that was used to describe children's involvement, offers a glimpse into the role of users at that time. Such phrases as, 'the subject's task', 'allow the user', 'children should be used' were common and all suggest that users, especially children, had little control in the research process". Indeed, we see a parallel here with the work with animal users in the early 2000s to the second decade of the century, which gradually has moved away from similar terminology with animal users, that somehow implies they are subjects rather than participants. Research methods levered with child users can in some instances be similar to those of adult users, only with the additional adaptations of certain techniques for the children's' ages, cognitive, and social abilities taken into account (Druin, 2002).

Druin notes that it is common for developers of new technologies to ask parents and teachers what they thought the children needed, rather than asking the child directly. Perhaps this forms the idea that children are dependent, not independent, and better represented by their 'all knowing' caretakers. This assumption that a caretaker can know more about preference or need than the child has been found to be problematic, which can likely extend to animal users. Druin notes that designers have their own biases about children, and some being parents themselves may feel they understand their needs. Young children have a more difficult time verbalising their thoughts, especially abstract concepts and actions (Piaget, 1971). For example, if a child becomes bored or frustrated, their reaction may be the same: walking away from the interaction or beginning a non-related task. When the child user disengages it may be difficult to discern the reason behind it, if they are too young to verbalise their feelings. One can envision similar issues arising with animal uses.

Another parallel between ACI and CCI; CCI was once thought to be mostly of interest to educators and child psychologists. Similarly, early technology for animals was thought to be of interest to biologists or animal behaviourists that were using technology to uncover additional information about the animal as an individual or species. Gradually, this has shifted to reflect the ubiquitous nature of technology and child or animal exposure to it.

Exploratory Research Approach: Ethnography

In order to apply user-centred design methods, researchers need to understand their users and the issues they may face; indeed, why they may need a certain technology developed in the first place. Ethnography is a qualitative research method often used to investigate complex social phenomena such as the culture of a community (Dourish, 2006). In ethnographic research, field studies are designed to capture social dynamics and the naturalistic contexts in which these take place, to try and understand the social relationships within a community and the perspective of its actors. To do this, the ethnographer observes and participates in the activities of the community for a period of time, in order to attain an in-depth understanding of a social group and their practices. In recent years, many interaction designers have used ethnography to better understand the people they are designing for, where the ethnographer becomes the 'translator' or 'cultural broker' between the group being studied and the designer. (Anderson, 1994; Dourish, 2006).

While for decades ethnography has been used to study human groups, more recently ethnographic research has been extended to other species, mainly to investigate relations, interactions and shared cultures between humans and other animals in multispecies communities (Kirksey & Helmreich 2010). While humans and dogs do not use what we call 'natural language' to communicate with each other, there is still a continuous dialogue between them (McConnell, 2009). In order to understand what these dialogues consist of researchers have been using *multi-species ethnography*. In particular, in the last decade, sociologists have demonstrated a growing interest in dog-human social interaction. Many canine ethnographies have been conducted over the years, some of which conducted at dog parks (Robins, 1991; Jackson, 2012), breeding facilities (Aro, 2003), or with family pets (Goode, 2007). These ethnographies focus on how dogs and humans express themselves to one another. Perhaps the most in-depth example of canine-human ethnography is provided by Goode's work *Playing With My Dog Katie*, which contains great detail of extended playful interactions with his pet Corgi, Katie.

ACI work in the area of computer-mediated human-animal interaction has leveraged ethnographic methods. For example, Weilenmann and Juhlin (2011) used a multi-species ethnographic approach to look at hunters' use of GPS dog tracking devices, reflecting on how interaction between dog and humans is affected when new technology is introduced (Weilenmann 2011). They found that the GPS device could change the hunter's perspective on the dog's intentions and thus supported different types of interaction with their dogs. Informed by Goode's ethnographic perspective, the authors did not make any assumptions on the meaning of the dog's behaviour, delegating that to the interpretations of the hunters. However, Mancini et al. (2012)'s multi-species ethnography of human-dog tracking practices proposes a framework that integrates the accounts of dog owners and ethologically informed observations of dog behaviour to interpret the sensemaking processes by which the dogs might attribute meaning to a technology. The research showed that the use of the tracking technology was changing the behaviour of both humans and dogs; for example, the authors report that some dogs had formed strong positive associations with the collar, as this had become a signal for upcoming long walks off lead. In one case, a dog owner pulled out the collar and demonstrated the dogs reaction, which was to stare intently at the collar wagging his tail until it is slipped on his neck (Mancini et al., 2012). The authors proposed that in order to understand how a dog might interpret and respond to a technology, it is important to take into account both the perspective of those, such as owners, who live with the dogs and share daily practices with them, and thus know them intimately, with expert observations of the dog's responses during specific interactions with the technology. Such observations could be made by the ethnographer with the support of canine behavioural experts and/or backed by appropriate sources from the literature on the subject.

2.3.3 User Centred Design with Animal Users

Resner (2001) borrowed from HCI the idea of user-centred design, reasoning that, since humans are a type of animal, user-centred design could be extended to other animals too. However, due to interspecies differences between animals and humans, Resner argued that all successful ACI interfaces must start with an understanding of the animals' basic physiology and psychology and take these into account (Resner, 2001). Species-specific characteristics were then used to inform his design of Rover@Home (see §2.2.6), a system that allowed dog owners to communicate and train their dogs remotely. Although no dogs took part in the development of the technology, this work explicitly discussed what the dog's physical and cognitive abilities implied he might prefer in a design. For example, considering that canines do not process 2-dimensional moving images the same we do, Resner decided not to use a video interface for the dog. Importantly, Resner worked intimately with a canine training team and took their feedback into consideration. Even though the design of the dog's interface was canine-specific, however, hearing commands came out of a speaker and having treats appear out of a machine is not part of a dog's habitual experience; therefore, many training sessions with the owner or trainer present had to take place before the dog could be left alone with his part of the interface. Additionally, in evaluating the system, Resner relied upon the owner's feedback to represent the dog's user experience, thus delegating to future work to explore the issue of evaluating such technologies from the animal's perspective. In his work there is also no indication of whether and how evaluation findings influenced any system's redesigns.

During the CAT's (§2.2.6) evaluation, the authors noted that the initial games were very human-centric, meaning that the human player tended to strongly drive the game. Also, they noted that some of the games were distressing to certain dogs or created stress for the humans, which appeared to create additional stress for the dogs, as dogs are known to identify and reflect their handlers' emotions (Custance and Mayer, 2012). Based on these findings, the researchers were able to improve upon their initial designs. For example, a real-time biofeedback sensor was introduced so the human could monitor their own physiological state throughout the game. CAT's evaluation did not only rely upon owners' feedback, but also took into account the observer's interpretation of canine body language (for example, wagging tails as a sign that the canines were enjoying the games), although in some cases it is unclear how this was measured (for example, when the authors mention that play would stop when the canine became tired, but did not describe what the signifiers of tiredness were). Similarly, it is not clear whether the dog was following commands or freely engaging with the system.

With Metazoa Ludens, the human-hamster game environment (§2.2.6), steps were taken to ensure that if the hamster did not want to engage, this would be clear to the human player. The participating hamsters were kept in their habitual cages, but for a couple of hours each day their own cage was linked up with a tunnel that led to the game-playing tank. To rule out that the hamsters entered the tunnel to play merely out of curiosity, the hamsters were given access to the tunnel for 1.5 hours before gameplay started and could at any time return to their cage. A whistle signified the beginning of the game, so, presumably, any hamster that did not want to play could learn to go back to his cage at this sound. The evaluation of the system considered how many times the hamsters stayed in the game area after the whistle blew compared to how many times they stayed in or went back to the cage. During a 6-week study the time the hamsters spent in the play-ground was shown to increase, demonstrating that the hamsters were choosing to increasingly engage with the game as time went on. The game's interface places the hamster and the human on an equal footing, because the human is no longer a huge physical presence but rather something the hamster can chase (a tunnel). In designing their system, the designers considered the fact that hamsters are known to have a natural instinct to run and tunnel, making the choice of incorporating a moving tunnel in the design appropriate to the hamster's behavioural characteristics.

Similarly, an important aspect of the Poultry.Internet project (§2.2.6) is its approach to evaluating whether the chicken jacket wearers wanted to engage with the system, for which the authors borrowed a preference test developed by Hughes and Black to measure poultry motivation (Hughes and Black, 1973). In this case, evaluation of the system was structured such that the chicken was always presented with two different coloured doors: behind one door the chicken would find food and water only, and behind the other door he would be picked up and the haptic jacket would be put on him. Over time the chickens strongly preferred to enter the room with the jacket, even when weights were added to the door leading to the jacket, but not added to the other door. They found that 73% of the time, the chicken chose to enter the door that led to getting the jacket put on. And, even with added weight to the door leading to the jacket, 70% of the time the chicken still chose this door. This work shows that if preference tests are suitably informed and structured, an animal can directly contribute to the design process at least based on whether he wants to engage with a prototype or not. Such preference tests are important in that they can safeguard the animal against human projection or assumptions and allow the animal to "vote with their feet". All of these approaches include the animal as a design participant, rather than an experimental subject, and make attempts to ensure the animal has some element of say in their level of engagement and involvement. The experimental design of both Poultry.Internet and Metazoa Ludens importantly allow the animal user to disengage at any moment and return back to a neutral environment. However, these situations may not always be possible for some animal con-designers. For example, working animals, that are participants, may be needed to be involved in the design process in order to make successful designs for technologies that they are required to use regardless of their level of comfort. For such participants, they have specific jobs and tasks they are trained for and will be executing regardless of the presence, or indeed the effectiveness, of a technological intervention. In these cases, participation may be more nuanced and complex. Hirsky-Douglas has proposed an adaptation of Arnstein's and Hart's ladders of participation, whereby the animal has different levels of participation (Hirskyj-Douglas, 2015). This proposed framework has a modified four rungs that include, from least level of participation to highest: Training, Freedom, Informed, and Power. Hirskyj-Douglas notes that without human involvement, wolves and wild domesticated dogs can self-organise. On the other hand, humans can easily manipulate dogs, given dogs established ability to work for primary motivators (toys, food). A dog may be non-participating when they are ornamental to the design process, or manipulated via primary motivators without allowing their preferences to be expressed. Moving up the ladder, a dog may become a participant when through its body languages and choices to engage and demonstrated preferences, it is being ‘listened to’ instead of manipulated. At the highest level of participation, the author proposes a conceptualised ideology of achieving where dogs can actually understand that they have an influence on the design by understanding that their actions can cause certain reactions.

2.4 Understanding Canine Users

Understanding canine biology is necessary to understanding them as users. While individual animals, human or non-human, possess individual characteristics, species largely share similar sensory, physical and cognitive abilities, and the behavioural propensities that derive from these. Thus, when designing for an animal, one must examine what is known of that particular species way of interacting with the world. Indeed, the more that is understood about a species, their way of interacting with the world and communicating with each other, the better the technology that can be designed for them.

When it comes to understanding canine biology, a lot of work has been done to understand canine abilities in relation to other animals, including humans. Presented here is an overview of the sensory apparatus of dogs - olfactory, auditory, visual, and tactile. Additionally, we review what is presently known about canine cognition, learning, and their unique co-evolutionary relationship with humans.

2.4.1 Dog Training

For designers to create technology for dogs with specialist training and jobs, some rudimentary understanding of dog training is required to understand the skillsets of these canine users. While there are a vast number of frameworks and systems of dog training, almost all modern-day dog training is based on the ideas of classical and operant conditioning (Hiby et al., 2004). By far the most prominent training system for dogs that are taught advanced behaviours (such as opening and closing doors or alerting to specific scents), is *clicker training* which is based on the positive reinforcement quadrant of the four quadrants of operant conditioning (Pryor, 2002).

Classical and Operant Conditioning

Classical conditioning is when an animal has an involuntary and reflexive response to an external stimulus. Operant conditioning is based on decision making and consequences. BF Skinner, the "father of operant conditioning", invented the Skinner box (also called an operant conditioning chamber), a chamber whereby animals, usually rats or pigeons, were isolated and could be experimented upon. Skinner focused on observable behaviour with this empirical approach (Skinner, 1963). Through operant conditioning, dog trainers use "shaping", a technique that shapes behaviours by rewarding for an increasing quality of efforts of the desired behaviour.

The four quadrants of operant condition are positive reinforcement, positive punishment, negative punishment, and negative reinforcement. Positive reinforcement is offering something the dog desires in return the behaviour the handler desires. Positive punishment is offering something the dog does not desire in return for a behaviour the handler does not desire. Negative punishment takes away something the dog desires when the dog performs a behaviour the handler does not desire. Finally, negative reinforcement takes away something the dog does not desire when the dog performs the behaviour desired by the handler. The following are examples to further illustrate each quadrant:

Positive reinforcement: If, every time a rat in a Skinner box presses the lever, food appears, the rat will increase how much they press the lever. They are learning that a particular choice leads to a particular outcome.

Negative reinforcement: Negative reinforcement starts with something adverse or unpleasant, and then removes the aversive. The taking away of the aversive is the reward. For example, an unpleasant noise that shuts off when a rat presses a lever.

Positive punishment: If every time a rat in a skinner box pressed a lever, an unpleasant noise (aversive) was made, this would decrease how much he would press the lever. A common aversive for children would be spanking or admonishing. This is often just called 'punishment'.

Negative punishment: Is taking away something the animal desires in response to certain behaviour. For example, a parent taking away a child's toy when they are complaining.

Clicker Training

Clicker training offers a distinct noise (created by a hand-held clicker) to act as a secondary reinforcer, that is, a distinct marker for desired behaviour that represents the actual reward (the primary reinforcer, usually food) (Pryor, 1997). Dogs (as well as other animals) are shown to work very well for a secondary reinforcer, as long as the relationship between the primary and secondary reinforcers remain strong. To draw an analogy relating to human behaviour, most humans will happily work for money without actually being given money immediately after each task they perform, as long as an agreement exists that they will, indeed, eventually get their salary. If the person started to doubt that what they were working for would actually be delivered (i.e., they started to not trust that the funds would actually appear in their bank account in a timely fashion), the human would become much less consistent in their response to the secondary reinforcer. Similarly, a dog will happily work for a secondary reinforcer if they still know that they will be actually rewarded with a primary one, but if a secondary reinforcer is backed up less and less with a primary reinforcer, they will start to slip in their behaviour.

2.4.2 Olfactory

The predominant sense for a dog is his or her sense of smell. A dog has an olfactory epithelium of approximately 170cm^2, in comparison to a human's approximately 10cm^2, giving dogs far superior scent capabilities. This means that a dog has as much as 50 times greater sense of smell than humans. An eighth of a dog's brain is devoted to processing olfactory signals. Olfaction is thus the sense that human and dogs have “least in common”, that is, the biggest discrepancy in our shared sensory ability. Patricia McConnell, a leading ethologist and animal behaviourist, writes that dogs “are designed as scent machines, with mobile nostrils: a special bony structure, the vomero-nasal organ, which hangs on to large scent molecules like Velcro; and an olfactory bulb in their brain that is proportionally four times larger than ours” (McConnell, 2009). While it can be hard to conceptualize what these measures of physical differences might actually mean, McConnell gives a tangible example, describing how dogs can “detect human scent on a glass slide that has been touched just lightly, then left for two weeks outdoors or four weeks indoors. It’s trivial for them to use smell to distinguish which stick you picked up and threw yesterday from all the other sticks lying in the yard” (McConnell, 2009). It is worth noting, however, that while a dog’s sense of smell is far superior to humans, humans do retain some abilities to distinguish smells that may be surprising, however, most of the effect of odour on humans may be on a subconscious level (Shepherd, 2004). Humans have been shown to be able to successfully identify their dog through odour alone (Wells and Hepper, 2000). Thus, there is some common ground between the two species when it comes to olfactory input.

Given their extraordinary sense of smell, it is interesting, but not surprising, the extent to which a dog can be trained to detect by scent. Some of the things dogs have been shown to detect are: oestrus in dairy cows, contamination in a water tank, accelerants, insect infestations (like bed bugs), microbial growth, wood rot, gas leaks, and toxins (Helton, 2009). Some of the more commonly canine-detected scents are explosives, narcotics, and more recently, cancer. Dogs can indeed smell cancer; the idea was first presented in the 1980s based on anecdotal stories of dogs showing intense interest in one part of the body that ended up having a malignant tumour. It has since been proven that dogs can be trained to detect bladder cancer in urine samples. Other studies have shown that breath, sweat and urine tests are all viable ways for dogs to distinguish between cancerous and non-cancerous individuals, sometimes even before other medical tests have been performed (McCulloch, 2006). Since tumours produce volatile organic compounds, it follows that dogs would be able to detect these changes. Finally, as mentioned in the introduction, assistance dogs are now being used more and more to smell dangerously low blood sugar in real-time detection in humans to help prevent hypoglycaemic attacks (Rooney et al., 2013).

2.4.3 Auditory

While dogs rely primarily on their sense of smell, they do also have excellent hearing. Hearing ability is superior in dogs with erect ears (as opposed to floppy ears), which act as amplifiers for incoming sounds, and in those who can swivel their ears in the direction of the sound (Heffner, 1983) and can move their ears independently, so that one ear may locate a sound and then both ears can catch the optimal amount of sound waves. Dogs can hear sounds over a wider range of frequencies and a greater distance than humans can. There is evidence that they may find high-pitched noises, such as the ones emitted by vacuum cleaners and other household appliances, uncomfortable or even painful. The upper range of hearing for dogs is 40,000cps (40kHz), while human hearing only extends to around 20kHz. There are some sources that state a dog's hearing range may even go up to 60,000cps (60 kHz) (Hefner, 1983).

2.4.4 Visual

Although there remains widespread misunderstanding about canine vision, with a persistent public perception that dogs are 'colour-blind', that they see the world in black and white, it has been demonstrated that this is not the case. Indeed, dogs do see colour, although their perceptual spectrum is limited. The retina of dogs contains two classes of cone photopigment, meaning that dogs have dichromatic colour vision (Neitz et al., 1989). Consequently, dogs see the world in yellows, blues, and browns. Again, this is important for a canine designer to consider. Colour is commonly used as a feedback or distinguishing characteristic on human interfaces. This can also be done for dogs, if their sight abilities are considered. For example, many dog toys are coloured bright red, presumably so that humans can see the toy easily, for example on green grass.

However to the dog the green and red virtually the same; the two colours both look shades of brown or grey to a dog (Figure 2.1). Because of this, some dog toy companies have started making dog toys with yellow and blue contrast that dogs will be able to see.

Figure 2.1. Human vs canine colour perception: canines, similar to men with red-green colour-blindness, cannot distinguish between green and red hues. *Source: http://stories.barkpost.com/why-dogs-watch-tv/*

Both canines and humans have binocular vision that allows us to perceive depth and distance. However, there are many differences that go beyond colour in vision between the two species. Dogs cannot detect fine vision details as well as humans; however, they are more sensitive to moving objects, very likely an evolutionary adaption for hunting. They recognize moving objects at up to 900 metres and stationary ones at 585 metres (Miller, 1995). When it comes to communicating visual with humans, some dogs are very responsive to slight visual cues from great distances, implying that they have the visual capacity for such small, distant visual changes.

While dogs have useful and sophisticated visual abilities, this does not necessarily mean that our technological visual interfaces are perceived the same way by canines. Electronic displays do not reproduce an object, but rather capitalize on our human visual physiology to communicate meaning. Studies have shown that dogs can distinguish between 2-dimensional digital objects and even show a left-gaze bias when viewing human faces and not dog faces or landscapes (Guo, 2009). While dogs have been trained to use touch screens for research purposes, this sort of training can take much longer than training based on physical human cues or sound cues. There is a lack of literature to determine the conceptualization process that a dog goes through when seeing objects or people they are used to seeing in 3 dimensions on a 2-dimensional interface.

2.4.5 Tactile

Like other social mammals, including humans, touch is important to dogs. Touch is a fundamental part of the human-animal relationship. A dog's skin has touch receptors at the base of every hair. Tactile communication is the first a dog learns before their ears and eyes open as young puppies. Dogs touch humans and other dogs as a way to express themselves, such as a dog that presses against their owner when they are scared. A gentle touch can have a calming effect on a dog. Dogs may also display protective touch by lying on top of a toy, or affectionate touch such as cuddling or licking. Dogs can also use defensive touch to tell another dog they want to move them. Touch is, for dogs, all about communication. There is limited research regarding a dog's ability to engage in the complex abstraction required to conceptualise that something remote that is petting them may be controlled by their owner. So, while humans have explored tactile communication, it is unknown whether a dog could understand that a device of some sort petting or otherwise touching them is communication from their owner. However, this does not discount it has a mode of interaction, especially since dogs are known to manipulate the physical world around them with both their paws and whiskers.

2.4.6 Physicality

Physically, dogs are an incredibly diverse species. Earlier in their developmental history, members of *canis familiaris* were fairly similar (Clutton-Brock, 1995); but humans started controlling their breeding, and selecting for certain behavioural traits, which has in turn influenced physical traits

(Trut, 1999). Dogs range hugely in size and weight, from the 2lb,7 inches tall Russian toy dog, to the 160lb, 30 inch tall Neapolitan mastiff. However, there are some traits all dogs share, such as a lack of dexterity and difficulty using precision with their paws. How a dog's breed effects how he interacts with the world. For example, retrievers are more commonly "mouthy" than other breeds (that is, they enjoy chewing, biting, and in general using their mouth to interact with the world), while some breeds are more likely to express themselves by barking. Some dogs are able to rear up to reach something, while others, such as the American bulldog are very "grounded" and not considered athletic and agile. But, while a dog's breed can serve to provide hints as to what he will physically be like, we cannot be sure that all dogs of the same breed have the very same capabilities.

2.4.7 Relationship with Humans and Learning Capabilities

Another integral part of designing technologies for canines is understanding their historical and present relationships with humans. Genetic and archaeological evidence shows that humans domesticated wolves at the latest 16,000 years ago, possibly as early as 33,000 years ago (Larson et al., 2012). They are the 'most domesticated' animal in terms of adapting to human communication. Here we briefly examine how they came to be that way and some of the particular adaptations that have developed in canines in their interactions with humans.

Hunting Instincts and Social Cognition

Dogs have shown to have an unusually high degree of social cognition when compared to other social mammals. When dogs are 'spectators' of controlled competitive interactions between a human and a dog, they demonstrate different behaviours based on the winner of the interaction, displaying different social preferences (Rooney, 2000). Dogs are better than great apes at reading communicative signals in a number of tasks and these skills are shown in even very young domesticated puppies, even those who have had little human contact, whereas wolves who were raised by humans do not show these same skills (Hare, 2002). When the attachment behaviour of hand-reared puppies, less socialized dog puppies, and wolf-puppies were compared, the dog puppies showed patterns of attachment towards their owners regardless of their level of socialization, while wolves were considerably less responsive to their owner, implying that these behavioural differences were result of the course of domestication, that is, genetic changes between wolves and dogs (Saetre, 2004).

While domestication has foraged a strong social bond between dogs and humans, dogs still share 99.9% of their DNA with grey wolves (Wayne and Ostrander, 2007), and share many of the same basic instincts. First and foremost, dogs, like wolves, are social predators. Behaviours pertaining to food acquisition are deeply imbedded. Even hundreds of generations of selective breeding that ignored, stylised, or even actively sought to eliminate predatory behaviour in various dog breeds have failed, in the vast majority of individuals, to stop dogs usually tracking, chasing, and biting moving objects. Those same hundreds of generations of selective breeding also preserved the strong tendency to form social bonds and the rich array of affiliative behaviour. Mech defines the wolf predatory sequence as consisting of six distinct behaviours: travel, approach, watch, attack, target, and capture:

Mech's Wolf predatory sequence:

1. Search (find prey, mostly using sense of smell)
2. Stalk (stealthy approach to prey)
3. Rush (move rapidly towards prey)
4. Chase (if prey flees)
5. Bite/hold/shake/kill (the prey)
6. Dissect and eat (the prey)

These behaviours are organized into three nested groups: predation attempt, prey encounter, and hunting bout (Mech, 2002). These instinctive behaviours are important to consider when understanding dogs' social hunting skills, and how they view humans versus other dogs or prey, which influence their play behaviours (Rooney et al., 2000). For example, it may be that dogs enjoy games of tug-of-war so much not because they are competing with humans, but rather because they view the game as a social collaboration with the human, like they would with a hunting pack, (that is, multiple wolves pulling on different limbs of prey at the same time to tear it apart). Similarly, the fact that many dogs delight in dog toys that emit a squeaking sound when squeezed, likely taps into their instinct to shake and kill small prey they would emit similar noises.

Communication with Humans

The co-evolutionary relationship between dogs and humans makes them uniquely qualified for more advanced forms of communication than other cross-species communication. In her *Companion Species Manifesto*, Donna Haraway writes that dogs and humans are "training each other in acts of communication we barely understand (Haraway, 2003)." It might seem minor, but the idea that dogs and humans are acting *on each other* instead of a one directional domination or submission is essential to moving forward understanding canine-human interactions; while it may be common knowledge that dogs are the favourite companion animals, it is only recently that it has been investigated how they got that way, and how their biology and our own has evolved as a result of this intimate relationship. Recently researchers have made great strides in tracing this unique relationship back to its beginnings of wild wolves and pre-canine humans, and there has been a shift towards the idea of co-evolution rather than human domination of canines; and towards the idea that we did not domesticate wolves, but rather they domesticated us, or the two species "adopted" each other. It is likely that the wolves first approached humans, rather than the inverse; wolves that were bold but friendly would have been tolerated, and over thousands of years this caused physical and behaviour changes. As the two species co-evolved, changes likely occurred in both. Physically, dogs developed floppy ears, and wagging tails (Trut, 1999). Behaviourally, dogs started to be able to read human gestures. Several studies have shown that the ability for dogs to interpret human gestures far surpasses any other mammals, including our closest relatives, chimpanzees and bonobos (Miklósi, 2002). As these biological changes took place in wolves and turned them into dogs, it is likely that humans were strongly affected by our relationship with dogs as well. Canines may even have been "the catalyst for our civilization" (Hare, 2002). This intimate, co-evolutionary relationship is still going strong today, where we see dogs more ubiquitous than ever in human society, still functioning as working animals and pets almost everywhere humans can be found on the earth.

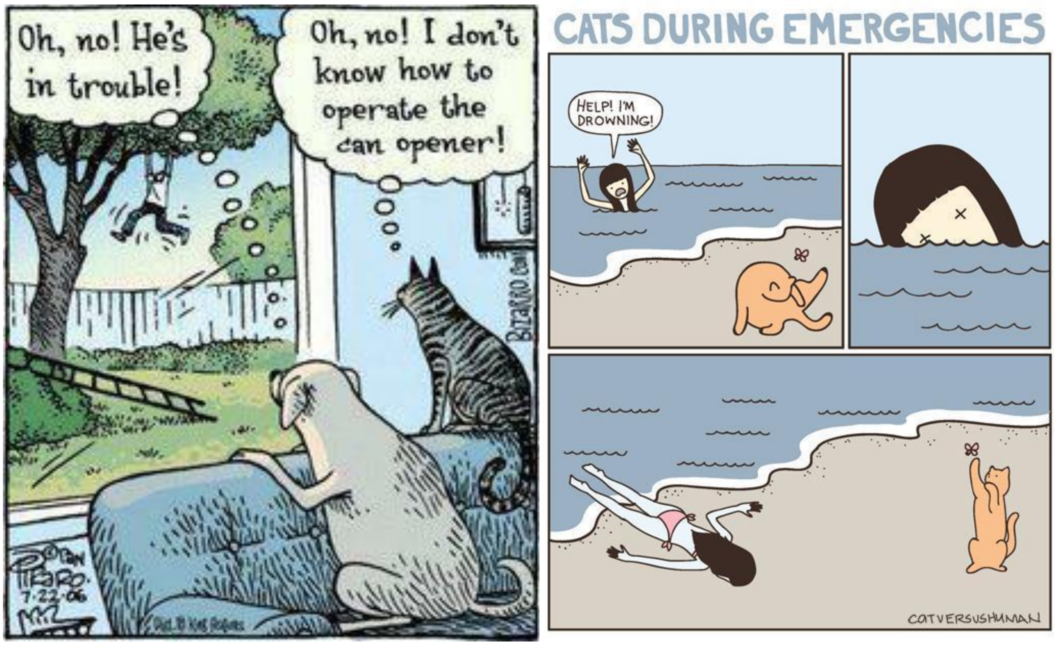

Figure 2.2. The contrast between a cat and dog's, the two most common domesticated pets in the world, reaction to emergencies is a recurring theme in cartoons. Dogs seem pre-disposed to notice and respond to a distressed human, more so than other domesticated animals. *Image sources: Dan Piraro 2006 and www.catversushuman.com (Yasmin Surovec)*

Dogs perceive 'minute changes to our bodies" and that they "assume each tiny motion has meaning". McConnell, and many canine behaviour experts, stress that tiny changes in environment or body language that we might think mean nothing can make a huge difference to a canine. Things like shoulders being slumped or straight, weight shifted back or forth on your heels, the depth of your breathing (McConnell, 2002) As touched on previously, dogs have been shown to be remarkably adept at reading human body language, with capabilities beyond that of even our closest primates. Puppies as young as 6 weeks can read changes in human eye directions that wolf cubs of the same age or adult primates cannot (Guo et al., 2009). While surprising at first, this actually reflects the dependence and close working relationships that domestic dogs have had with humans over the last thousands of years. Primates, for example, have not had biological reason to develop these remarkable skills, as their survival had not been dependent on it. Whilst dogs, meanwhile, may have been inheriting these capabilities since wolves and humans first started a relationship. While researchers are excited to note these differences for the studying of evolution of human cooperation and communication skills, for canine-computer interaction these concepts hold great meaning as well. For example, any technology has to consider that a dog will likely look to the human for cues on how to engage with it regardless if the human is aware of it or not.

Stress and Stress Responses

Dogs, like other social mammals, experience a range of emotions based on their environment. Lack of predictability and control of their environment can cause stress in dogs. When a dog learns that he or she has no control of the outcome of a stressful situation, this can result in a phenomenon called “learned helplessness”, which is considered a depressive state. In working dogs, environmental factors that the dog cannot control such as unpredictable behaviour of the humans around them can contribute to stress. In the particular case of Diabetic Alert Dogs, when their owner experiences hypoglycaemia, the dogs are at risk for finding themselves in a potentially stressful situation where their owner has decreased cognitive function or even becomes completely unconscious. It is possible that repeated occurrences of such situations - where the dog is unable to wake up their owner or successfully alert them as they are trained to do - contributes to overall stress in an assistance dog.

2.5 Chapter Summary

In this section, we have seen that, while researchers take different approaches across disciplines to designing for animals, methods from human computer interaction and interaction design have been applied with some success, specifically those that focus on the specific needs and abilities of the user and involve them at various stages of the design process. Thus, understanding the characteristics of the target species is the first step in design technology for them. In particular, when designing for assistance dogs, we must first understand their specific requirements as users. In the next section we therefore provide an overview of work relating to canine physical, sensory and cognitive characteristics.

We have reviewed the landscape whereupon this doctoral research is situated: that is, designing specifically for canine users, that have different physical and cognitive characteristic than ourselves, but also a unique relationship with humans that make them especially able to work and communicate our own species. Having identified that most work designing for assistance dogs has focused on controlling their behaviour, we move to expand the less-explored domain of giving an assistance dog a tool that he or she can choose to use if necessary, given that such tool use for animals and indeed dogs is already naturally occurring. In order to accomplish design effectively for this relatively new user group, we need to explore various methodologies we can use for the design process, which we will review in the next chapter.

3

Methodology

3.1 Introduction

This chapter describes the rationale for the overall methodological research approach used for this thesis. In Chapter 1, we saw that there are many dogs that have important jobs where they perform complex tasks to support humans. In Chapter 2, we saw that while researchers are developing an increasing number of Animal-Computer Interaction systems, the technologies to support working dogs are still limited, especially technologies which place working dogs in an active role and focus on their needs as users. To investigate what potential practical tools could be developed for dogs in these situations, we focussed on a particular subset of working dogs; assistance dogs, who may find themselves alone with their assisted humans in an emergency. Thus, as mentioned in Chapter 1, the primary research questions driving this work are as follows:

RQ1) How should an alarm be designed to be usable by assistance dogs and provide them with the best possible support for the critical task of dealing with an emergency on behalf of their assisted human? In particular, what design features and interaction mechanisms might help dog users learn how to effectively engage with the technology at the right time? Can HCI design principles and goals commonly referred to when designing interactive systems for human help design for canine users?

RQ2) How should interaction designers proceed with designing technology for a user of a different species? In particular, given interspecies differences and communication barriers between canine users and human designers, how can the latter ensure that what they design is indeed usable by the former? Can we draw upon existing HCI methodologies, such as user-centred and participatory design, to facilitate the design process and achieve specific design goals?

To answer these questions, we needed research methods that would allow us to:

1) Understand the problem space; that is, understand the tasks that assistance dogs perform and the challenges they face, to identify potential technological interventions that could support the dogs in an emergency;
2) Include all human and canine stakeholders directly in the design process; elicit requirements from, as well as design, prototype and evaluate our prototypes with canine and human users, to best support both in day to day life.

To this end, we adopted a flexible, qualitative, ethnographic approach, which the rest of this chapter describes in more detail. §3.2 provides an overview of the qualitative methods used, describing our motivation for taking a multi-faceted, ethnographically informed approach. §3.3 briefly explains how the research was organised into four research phases consisting of five studies; the exploratory phase, requirements elicitation phase, design phase, and home testing phases. An overview is provided for each research phase, which the next five chapters of this thesis will cover in greater detail. §3.4 gives an overview on data collection methodology, while §3.5 follows with an overview of the data analysis methods used. §3.6 addresses ethical considerations and the consent process of all participants. Finally, §3.7 provides a summary of the chapter.

3.2 Research Approach

Here we briefly give a general overview of our research approach. Note that individual study chapters will provide more detail on specific methodology for that particular study: this section is intended as an overview.

We selected investigation methods that allowed us to collect rich qualitative data. To deal with the complexity of the problem space, we used different methods to capture different aspects of what was going on, including contextual inquiry, naturalistic observation, informal and semi-structured interviews, the use of physical probes, rapid prototyping, usability testing, and in-the-wild evaluation. The work was ethnographically informed. In particular, we wanted to be able to design technology that supported assistance dogs, to do which we needed to develop an in-depth understanding of the dogs' daily lives, their environment, their daily tasks, the skills they acquire during training, the training process they go through, and so forth. A description of these data collection methods is covered in § as an overview, and then within each study further detail is provided.

To analyse the resulting qualitative data, we took an inductive, or grounded approach. Inductive, also called bottom-up coding does not try to fit into a pre-existing coding frame, but rather is driven by the data itself (Fereday and Muir-Cochrane, 2008). This approach was necessary for work that is in a new area, where there are not existing frameworks or well-defined taxonomies. Inductive coding was performed on all collected in all five studies, which meant that the analysis of the data started from a basis of information in the exploratory study gradually grew to form themes. A description of the thematic analysis is provided in §3.6, and then within each study further detail is provided. For internal validity, this work relied on knowledge of multiple researchers, and triangulation with experts that had a large expertise of the subject domain but did not record or transcribe the data first-hand. External validation relates to what extend a study's finding are generalisable. However, with an ethnographic approach, the aim is not always to achieve generalisability. This limitation is discussed further in section. The studies in this work provide detailed enough data to allow other researchers to interpret on a case by case basis, rather than creating a totally generalisable model for future work.

3.3 Research Setting and Participants

For this research, we collaborated with Medical Detection Dogs (MDD), a UK organization that trains dogs to detect human bio scents, including diabetes and cancer, and that provides medical detection dogs for people with medical conditions such as diabetes. This collaboration gave us access to a group of assistance dogs and their owners, handlers, and trainers.

The charity was founded in 2008 and has upwards of 100 partnerships placed around the UK. They are the only organization in the UK that is certified to train Medical Alert Assistance Dogs (MAADs) via the governing body of Assistance Dogs International. MAADs are trained to assist individuals who have to manage complex health conditions. The dogs are taught to identify the odour changes that are associated with life-threatening medical events. Currently the majority of their MAADs dogs work with people with diabetes, that is, they are DADs (Diabetes Alert Dogs). However, MDD also provides medical alert dogs for those with other very dangerous health conditions, including Addisonian crisis which causes severe pain, convulsions and unconsciousness that can lead to collapse and hospitalisation. They continue to investigate other debilitating and potentially fatal conditions which the dogs may have the ability to help such as Postural Tachycardia Syndrome (POTS), Ehlers Danlos Syndrome (EDS), Congenital Central Hypoventilation Syndrome (CCHS), and a variety of severe allergies. While the training centre is located in the central region of the United Kingdom, MDD support these partnerships all over the country.

MDD also trains dogs to detect human cancer from human tissue samples. Because dogs are able to detect tiny odour concentrations, around one part per trillion (the equivalent of one teaspoon of sugar in two Olympic sized swimming pools), they are potentially able to detect diseases, such as cancer, much earlier than is currently possible, and the organization's goals with cancer detection dogs are "to assist scientists through our research into the development of electronic systems (E noses) that will assist in the early detection of cancer through cheap non-invasive tests", and to "provide additional testing for cancers that are currently difficult to diagnose reliably, such as prostate cancer". Thus, the organization has two different types of scent detection dogs that they train that have a similar goal: to use dogs' impressive olfactory abilities to save human lives.

We conducted a range of studies with participants from MDD, thus the organization had a strong influence over who was selected to participate in the research based on timing issues related to the implementation of their training protocols, as well as the personal situation of their clients and the availability of their dogs and trainers. In particular, trainers selected participants among their clients, whom they thought would be suitable based on how long dog and owner had been working together. Thus, decisions like the age, gender, and size of canine participants, and age, gender, and other demographic characteristics of human participants were not in our control.

3.4 Research Phases

The research was divided into four phases (Table 3.1). The first phase was exploratory and consisted of a study aimed to understand the training, tasks, and working environment of medical detection dogs. The second phase consisted of two studies: one that focused on eliciting requirements for human users, and another that focused on canine requirements, aiming to identify what types of interaction (i.e., biting, barking, touching, nudging) would be effective ways to control the interface. The third phase saw the development of a low fidelity prototype and, through design iterations, resulted in a high-fidelity prototype. The last phase then involved the testing of a fully functioning prototype into home environments where it could be evaluated in-the-wild.

This thesis adopts an incremental, developmental approach, where the findings produced within each phase of the research builds upon the previous findings, i.e. the analysis in Phase 1 produced certain requirements and potential models which were integrated into the design of Phase 2, while the findings in Phase 2 are further addressed in Phase 3. From this perspective, rigour is achieved through critically assessing the evidence available and recognising the potential limitations of resulting interpretations.

Phase	Description	Methods	Materials	Setting	Data
1	Exploration	Informal interviews, contextual inquiry	None	Training centre	Qualitative
2	Requirements	Semi-structured interviews with human participants, rapid prototyping and material probes used to "interview" canine participants	Environmental, off-the-shelf	In-home, Training centre	Qualitative
3	Design	Informal interviews, participatory design, rapid prototyping	Low fidelity to high fidelity prototype	Training centre	Qualitative
4	Home Testing	In the wild evaluation	High-fidelity prototype in the home	In-home	Qualitative

Table 3.1. A comparison of different elements of each study across the four research study phases: the first study was exploratory in nature, relying heavily on contextual inquiry and ethnographic observation. The second phase elicited requirements from canine participants using readily available material prompts already in the environment or at very low cost. The third phase used rapid prototyping that began with a low fidelity prototype and resulted in a high-fidelity prototype after several design iterations. Finally, the last stage involved evaluating the high-fidelity prototypes in the home environment.

Dog	Exploratory Design Study	Lab Testing	Home Testing
Sullivan	X		
Marla	X		
Judd	X	X	
Lady	X	X	
Sebastian	X		X
Goliath			X
Evie			X
Jessa			X

Table 3.2. Matrix of all canine participants across all prototype studies. This table displays all of the canine participants that participated directly in the design process, across all phases, in one place. This same table appears in each study chapter for convenience, with the appropriate column highlighted for the phase the chapter discusses. Sullivan, Marla, Judd, Lady, and Sebastian all took part in our initial exploratory study described in Chapter 4. Then, Judd and Lady continued to the next study as well, where they were presented with more actualized but still non-functional prototypes. Four dogs- Sebastian, Goliath, Evie, and Jessa- tested prototypes in their home environments.

Partnership	Exploratory Design Study	In-Depth Interviews	Home Testing
Caren & Sebastian	X	X	X
Catherine & Merlin		X	
Yvette & Nemo		X	
Tim& Goliath		X	X
Karen & Evie		X	X
Ray& Jessa		X	X

Table 3.3. Matrix of assistance dog partnerships across different study phases. This table displays all assistance dog partnerships (that is, a human owner with their long-term live-in assistance dog) that participated in our studies. One partnership, Caren and Sebastian, participated in all three phases, from the exploratory study to eventually home testing. Other partnerships, Yvette and Nemo and Catherine and Merlin, participated in our home interview study but then did not continue to do home testing. The other four partnerships that did the home interview study did continue on to do home testing with prototypes).

3.4.1 Exploratory Phase

Exploratory research can be useful when first entering a new research area, to understand the existing practices, which can help direct research design, data collection, and selection of participants (Stebbins, 2001). Prior to the start of this work in 2013, limited work had been conducted exploring the application of existing user-centered design principles to understand the needs of assistance dogs. Our first phase thus sought to gain familiarity with what problems and challenges these dogs face while supporting their assisted humans. In addition, this phase sought to understand the working dynamics between humans and dogs, and the training process by which an assistance dog is able to learn how to do his or her tasks.

We entered a busy working dog training environment to experience first-hand the training processes for the scent detection dogs, as well as the relationships and dynamics between the assistance dogs, their trainers, and the vulnerable individuals whom the assistance dogs were partnered with. Upon entering this environment, the goal was to identify the need for potential systems and further explore requirements (both canine and human) for such a system. To this end, different activities and types of data collected were used depending on the situation.

Contextual Inquiry and Talk-Aloud protocol

We relied heavily on contextual inquiries, which combine observation with self-reporting and help to understand specific work roles and specific tasks, and to scope opportunities (Holtzblatt & Jones, 1993). Contextual inquiry can produce very detailed data to support complex tasks, such as the tasks that assistance dogs with specialized training execute. Indeed, by observing working canines in their natural work environment, and by being introduced to both routine and new tasks, we could create a record of the range of tasks different types of assistance dogs do (for example, alerting their owner to low-blood sugar) and the challenges associated with each task.

As a way to implement contextual inquiry, we used a talk-aloud method. Talk aloud (also known as think-aloud) are protocols is a way to gather data in a range of areas, including psychology and a range of social sciences, as well as product design (Someran et al., 1994). Think-aloud protocols require participants to "think aloud" while they are performing a set of tasks. Participants are instructed to say whatever comes to their minds while completing the task, which gives he observers insight into a participant's cognitive processes rather than their actions alone. Participant verbalisations can then be transcribed and analysed. Talk-aloud is similar to think aloud, but the focus is on having the participants describe their actions instead of other thoughts, which may be more objective in that the participants are reporting how they go about the task rather than justifying their actions. Kuusela and Paul state that think aloud protocols are distinguished into two different type of experimental procedures: concurrent think-aloud protocol, collected during the task, and retrospective think-aloud protocol, gathered after the ask is finished (Kuusela and Paul, 2000). Retrospective think-aloud often utilises video recordings such that the participant can walk the researcher through their actions as they are played back.

During our studies, dog trainer participants were encouraged to talk-aloud as they worked with their dog, providing a real-time, free flowing descriptive narrative of what was going on. This allowed them to explain to the researcher the various dynamics between the dog and the handler that the researcher would otherwise not be privy to. It allowed the trainers, who have specialized knowledge and understanding of the canine training process, to communicate to the researcher their interpretation of what was going on. Without this real-time interpretation (recorded with audio or video for subsequent analysis) we might not have been able to follow along with what was happening between the dog and the handler, or might have missed important nuances.

This talk aloud method was consistent with the existing culture of the training centre: the trainers at the centre often worked together to understand the dogs' body language and to make training decisions; as a result, there was often a continuous verbal dialogue between trainers, and sometimes also with other staff, clients or visitors in the room. Our overall ethnographic approach lent itself to capture this open, dynamic working culture.

It is worth noting that the findings of this phase informed the methodological approach to the next phase. For example, it led us to think that using a rapid-dynamic prototyping method would be useful in this environment; with multiple dog-trainers on-hand to offer real-time feedback on the dog participants reactions, having many materials on hand to work with could mean that the designer was able to make a change or follow a novel idea on-the-fly.

3.4.2 Requirements Phase

The result of the first, initial ethnographic study uncovered a need for some sort of alarm system for dogs to use in emergencies. Having established this need for technological intervention, we now wanted to establish requirements for such a system. Our goal for this phase was to answer the following questions: firstly, what were the basic (human) requirements for such a system? What did assistance dog owners need during emergencies that could help their dogs to help them? And secondly, what were the interface requirements for the dog users? We wanted to investigate different ways in which it might be possible for a dog to interact with a device (for, by biting, pulling, nudging, touching, barking, etc (see §6.2.5). From the previous phase, we had learned that the collaborative, open research environment we were studying meant that we could get real-time feedback from the trainers on the dog's experiences with an interface. To elicit such a feedback, we used *rapid prototyping* as a form of participatory design to include dogs in the design process from its early stages. Rapid prototyping is a participatory design methodology that allows for flexible, on-the-fly changes to prototypes based on participant interaction (Dey et al., 2001). By using low cost materials that would allow us as researchers designing novel interfaces for animal participants to be able to quickly adapt to user requirements that may have been hard to anticipate.

Our initial prototype designs were low fidelity and non-functional, to allow us to focus on the canine interaction part of the design. Initially, a variety of different interface concepts were considered (see §6.2.5). The discussions with trainers used the prototypes as probes, that is, as talking points that both researchers and dog trainers could physically handle design components to facilitate design assessment and decisions. Finally, when the three different types were built, the canines were brought in as participants to see how they engaged with the prototypes.

3.4.3 Design Phase

Based on findings from the requirements elicitation phase, we developed an initial high-fidelity functioning prototype. We created several high-fidelity prototypes, which we tested with assistance dog users and their handlers, to identify which design features might best facilitate the dogs' 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.

The findings of the previous study indicated that the dogs' interaction with the alarm may be cued in various ways and that the dog may interact with it with varying levels of autonomy. For example, we knew that during very serious emergencies, a dog might have little to no direction from their handler when they need to interact with an interface. Therefore, in this study 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. 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 on varying cues. We observed both spontaneous and instructed behaviour in the dogs, and recorded feedback from the trainers interpreting the dogs actions and responses. The dog and trainer partnerships were presented with different iterations of the prototype across the span of several months. 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 be less so. Through the trainers' description of the training protocols and process, we were able to understand not only how the dog would engage with the device, but also how the dog would learn to engage with it. 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. During this phase 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 trade-offs might need to be made.

3.4.4 Home Testing Phase

Before starting this final research phase, we had implemented a functional prototype and had conducted some user testing as part of the design process. However, we now wanted to see how a functioning system would work in naturalistic settings. Unlike previous studies, which focused on understanding the problem space of how working canines can deal with an emergency situation and other daily challenges they face, this phase looked at specific usability of an overall system and at the ease of use in specific settings and features across different users in the wild. Having developed a high-fidelity prototype that worked well in a controlled environment (i.e. the training centre) we sought to evaluate the same system in-the-wild (i.e. in clients' homes), so as to expose any usability issues related to the environment the system was actually intended for, as well as more generally investigate the effect that the introduction of the device to the home environment had on both the dog and handler. In-the-wild studies have been important in demonstrating how new systems, devices and services are adopted as opposed to whether they match usability or other criteria (Rogers, 2011). In-the-wild interventions allow researchers to observe how people make use of a technology, where the goal is not to adjust to existing practices, but rather understand existing practices so as to create a technological intervention. Due to the newness of the subject area and complex context-specific environments for which our technology was intended, in-the-wild evaluation made sense (Rogers, 2012; Crabtree, 2013). As a part of this approach, we did initial home visits to assess the environment in which the prototype would enter, to determine a suitable location for the device for testing and to discuss practicalities. Participants were selected from the same assistance dog training organization as in the first two phases of study. After an initial home visit, a follow-up visit was done to to observe the dog and handler with the device; during this visit participants were further interviewed on their impression of the device and their dog's interaction with it. In some cases, the device was left partially installed in the home (i.e., locally functional but not setup to make any outside contact) and a final visit was done to collect the device and de-brief with participants.

3.5 Data Collection

Here we review our overall data collection methodology. The individual study chapters will go into more details about participants, data collection methods and procedures for each study; here, we briefly provide an overview to provide motivation for the collection methods used throughout the thesis.

3.5.1 Data Types

Following from the qualitative approach presented above, methods were selected in order to result in a rich data set with plenty of descriptive information. This richness of data was a reflection of the exploratory nature of the overall thesis work that permeated all five studies.

The form of data collected varied across studies, depending on the research approach and activities for that particular study (keeping in mind that all studies adapted an ethnographic, qualitative, exploratory approach) For example, field notes were used to provide data in situations where audio or video wasn't appropriate, such as when recording would have distracted the participants or resulted in a less naturalistic research setting. Study 1, being the most exploratory in nature, had the most open-ended approach. Gradually, as the focus narrowed, with interviews becoming more structured and contextual inquiry leveraged to guide observation. Throughout all phases of the studies, interviews with participants were fundamentally informal to allow for an open and exploratory dialogue between the researcher and participants. However, in later phases interviews did become progressively more structured, with interview prompts becoming more standardized across participants as research aims became more specific.

3.5.2 Procedures for Data Collection

The basic procedure for data collection in each study was as follows:

1. Provide a verbal explanation to the participant of the research activity.

2. Obtain written consent for participants (humans gave consent for canine participants)

3. Execute research activity

3.5.3 Video

In addition to field notes, interview notes and transcripts, and audio recordings, in some studies that involved canine participants, video was used to provide an objective record of canine and human users' interactions with each other. All footage was collected on a canon digital ultra-portable camera which was non-obtrusive. The camera was mounted on a tripod on floor where necessary to get a side or wide view of the canine participants interacting with prototypes. The majority of this video footage was of participants that were dog trainers, as they were comfortable having all sessions recorded, in their place of work. We collected much less footage of assistance dog owner participants, due to the more sensitive nature of their footage, a reluctance to record in the home. However, we did still collect participant footage in where possible, as a reflective tool for the talk-aloud method and also as a tool to triangulate observer interpretation of data with dog trainers.

3.6 Data Analysis

Due to a high volume of mixed forms of rich, descriptive data, in all studies we transcribed data in a focused manner, that is, we coded transcriptions primarily around noted events (by timestamp), and also reviewed the video data in respect to the research questions, and in respect to the themes that had been identified from previous studies, while still maintaining a bottom-up approach to analysis.

3.6.1 Thematic Analysis

Thematic analysis is a qualitative method for "identifying, analysing, and reporting patterns (themes) within data" (Braun and Clarke, 2006). Thematic analysis can be either a bottom-up or top-down approach to data analysis. For top-down approaches, some existing themes or frameworks are required. Bottom-up analysis is often used for exploratory work. Hence, all of the studies for this thesis were analysed bottom-up (also called inductive).

3.6.2 Video Analysis

Researchers often attempt to balance intrinsic biases that can stem from single method, single observer studies by combining multiple methods, theories, or observers (Brewer, 1989). In this thesis' work, this was addressed primarily by using multiple expert participants to evaluate the interactions that occurred. To understand what canine participants were doing, we needed to rely on interpretation by experts, that is, the dog trainers themselves. Because of this, we collected video recording of canine interactions, to serve as a visual reference of canine body language, and to allow re-examination of the interactions at a later time with additional trainers. Without this video recording, important observations relating to canine body language or behaviours could have been missed. Indeed, during this phase it became apparent how video is especially important when working with another species of user. For example, without a recorded video reference, meaningful complexities and subtleties of canine-human communication, such as the twitching of the dog's nostrils or minor angle changes of a dog's tail could be missed if not video-recorded, especially if the researcher is not a professional dog trainer. When reviewing the video data, in some circumstances the primary investigator would examine the video, take notes on a particular §9.5, and then compare these notes with another member of the research team to see if similar conclusions were drawn. This allowed multiple researchers access to evaluating data rather than only those present at the time of the data collection.

3.7 Ethical Considerations and User Consent

This research complied with the research ethics protocol outlined in the 2016 publication (Mancini 2016) as well as with Open University's animal ethics regulations. At the beginning of each study, participants were briefed on the purpose of the research and any questions they had were answered. They were given a form to sign that outlined the following:

1. The study adhered to Open University's Animal-Computer Interaction (ACI) Research Ethics Protocol.
2. The research was in compliance with the Data Protection act, and personal data would be kept secure and confidential (not released to any third parties).

By signing the form, participants were accepting that:

1. Various forms of data to be collected to be used in anonymous form in any written reports
2. Acknowledging that before using any media, their written consent would be sought before using an identifiable material.
3. Data for this study was collected in private spaces (participants homes and in assistance dog training centres).

Uttermost consideration was given to the need to use research methods that included animal users in the design process while prioritising their welfare. Unlike human users, who can give informed consent, animal users may not understand their involvement with a study or user experience situation. In considering the ethical implications of research with animal participants, we considered the differences between human participants and non-human animal participants. Both user groups are capable of experiencing stress or discomfort (Moberg, 2000). However, only the human can explicitly provide informed consent, since human users share a language with the researchers that allows them to clearly state what they want. Because of this, this research treated canine participants similarly to children participants whose parent or guardian is responsible for representing their interests and ensuring their welfare at all times. However, there are potential discrepancies between what the animal is experiencing and what the owner may assume the animal is experiencing based on their own projection. We thus needed to rely on the trainers to assess the dogs' inner state as best we could throughout each study session, rather than only collecting consent upfront from the owners.

3.8 Methodology: Summary and Discussion

This chapter has presented an overview of the methodological strategy for this research: to use multiple, flexible qualitative based methods to explore the problem space and identify requirements for assistance dogs working during emergencies, and how to include them in a design process to best create a device for this situation. We have highlighted commonalities and differences across various dimensions (participants, collection methods, analysis, materials, and setting) of the four phases of study (exploratory, requirements elicitation, design, and home testing). The application of these methods produced rich data that helped us identify specific requirements for specific use cases for real-life applications.

4

Exploratory Study

This chapter will describe the initial exploratory study of this doctoral work, which took place over a period of three weeks at a scent detection dog and assistance dog training centre. We will examine our motivation for the study, the research approach and methodology used, and the findings of the study. Finally, we will discuss the findings and how they informed the next study phase of the work.

4.1 Motivation

As discussed in § 1.3, assistance dogs are often at a disadvantage to humans when interacting with human environments and technology. We wanted to see if there was specific technology that could be developed to support these or other working dogs in situations where they are especially disadvantaged. We thus began with a study to explore existing methods of communication between working dogs and their human handlers, to see whether there is a need for technologies to support these partnerships. The goal was to understand what sort of specific challenges these dogs face, and, based on this understanding, identify problems that can be addressed through designing specialised technologies. For instance, we were curious if there were any tasks that working dogs routinely execute that could be automated, or any working tasks that are physically challenging to dogs, or any ways to communicate between dogs and humans in working partnerships that could be enhanced by use of novel interfaces.

Ethnographic approach for exploratory study

Since this study was very exploratory in nature, we used an ethnographic approach to allow for immersion in the environments of working dogs and to gain as much familiarity with the dog's jobs as possible in a short time period. We sought to gain a picture of the working dynamics between human and dogs, and the training process by which a canine worker is able to learn how to do his or her tasks. By observing these working partnerships in action, our aim was to allow potential technological interventions to unfold organically, and to then, when necessary, use a more directed approach to further explore these potential interventions.

4.2 Research Approach and Methodology

4.2.1 Participant Selection

This study was carried out at scent detection and assistance dog training centre, Medical Detection Dogs (MDD), in Buckinghamshire, UK. MDD was an ideal organization to have participate in the study, due to it being one the most diverse assistance dog training centres in the UK. Of the seven registered and certified training centres in the UK, MDD is unique in that they train a variety of types of assistance dogs, many of which are trained with scent detection skills in addition to the other basic assistance dog skills. MDD is also the only organization in the UK that trains cancer detection dogs. Within the organization, specific canine and human participants were selected based on who was actively working at the centre for the duration of the study.

4.2.3 Data Collection Methods

As described in §2.2.2, multi-species ethnography has been shown to be an effective and emergent method of inquiry when investigating situations involving both human and non-human animals interacting. Because we wanted to understand the complexities of human and animal relationships rather than simply compile a list of tasks that the partnerships face, we relied on multispecies ethnography as our primary mode of investigation. That is, we took a qualitative, ethnographic approach as discussed in Chapter 3, with the added element that animal participants were observed and 'interviewed' as well with a goal to understand the motivation, habits and experience of the animals In each situation as well as the humans. The aim was for the participants to not be viewed only through a lens of human experience but rather in their own right. Following standard practice, ethnographic interviews combined alternating immersive observation with one-on-one interviews to follow-up observations, with notes and audio used as the form of data recording.

Contextual inquiry

Contextual Inquiry is an ethnographic interviewing technique that is used to gather qualitative data about participants – their goals and motivations. We used contextual inquiry by observing participants conducting workplace tasks (for example, a handler testing a dog to see if a certain scent was present). In-line with contextual inquiry practice, we observed the participants doing these tasks in their natural setting, and also asked them questions about what they are doing and why during the tasks. If we had a question about a dog's specific behaviour, we asked their handler to explain on their behalf.

4.2.4 Potential Limitations

One anticipated problem was that of interpreting canine body language and behaviour. As non-animal behaviour experts, there is room for misinterpretation or missed data when observing, recording, and interpreting the behaviour of canines. This was addressed by whenever possible by deferring to the trained professionals to interpret any observed situations. We worked closely with trainers so that we were able to clarify any behaviours that were ambiguous to the primary investigator. The trainers were also available to view video footage and clarify their interpretation of canine behaviour when needed.

Another potential limitation of this study was using data from only one working dog organization. By selecting a centre that trains scent detection dogs and assistance dogs, we sought to identify existing themes in problems that working dogs faced. However, the selected organization, MDD, does not include many important groups of working dogs, such as: search and rescue dogs, explosive detection dogs, Hearing Dogs, or Guide Dogs for the Blind. However, working with only one organization was necessary from a practical standpoint, as taking a survey of all types of working dog programs is beyond the scope of this PhD.

4.2.5 Ethical Considerations

Ethical approval was sought before conducting the study. Human participants were given a consent form to sign (see Appendix B). They also signed the same consent form on behalf of any canine participants, which were in this circumstance given consent by their human guardians. We believed the study presented very minimal risk to physical or psychological harm for both canine and human participants, as the study was primarily observational in nature and we did not aim to have any of the human or canine participants perform any actions they did not already do routinely.

4.2.6 Procedure

The study was conducted over a period of three weeks, during which I, as the primary investigator, immersed myself in the environment of the training centre. During week one, I sat in on training sessions and staff meetings, assisting the trainers when they requested. Additionally, I engaged directly with the dogs, playing, walking, and doing basic training exercises independently (again, when requested to by the trainers). During weeks two and three, I continued this level of engagement, additionally asking staff specific questions and also recording training sessions with video. I also had the opportunity to interview two Medical Detection Assistance Dog (MAAD) owners that visited the centre. To understand these partnerships, I directly observed their interactional dynamics both ordinarily and also during working sessions where the dog accurately detected medical issues. Interviews were unstructured and casual and took place between scheduled training sessions, such as during a lunch break or rest period for the dogs. I took ethnographic style field notes throughout all observations. Whereas interviews with assistance dog owners and trainers were only recorded by notes or audio, dog training sessions with the dog-trainer participants were video-recorded where possible so that they could be later analysed and transcribed.

4.2.7 Data Analysis

During the analysis, some parts of the transcribed interviews and video footage were coded inductively (that is, allowing the codes to emerge from the data). The codes were then used to form the themes:

Theme	**Codes**
Ways different species communicate in conversations Subtheme: Object-as-communication	Training-Practices-ClickerAsConversation; Training-Practices-Clicker-MissedClick; Training-Practices-Clicker-Shaping Training-Practices-Trainers-Collaboration; Training-Practices-Trainers-Validation; Training-Practices-EventMarkers; Training-Practices-Object-Bringsel; Training-Practices-Object-Bloodkit; Training-Practices-Object-Toy
Alerting behaviour variations and practices in current registered medical alert dogs	Alert-Dogs-Alerts-Missed; Alert-Dogs-Alerts-Successful; Alert-Dogs-Alerts-Objects-Supported; Alert-Dogs-Alerts-Frustration; Alert-Dogs-Alerts-Ambiguity;
Sources of stress and problem in lives of assistance dogs and their owners	Medical-Condition-Stress-Healthcare; Medical-Condition-Stress-TrainingMaintenance; Medical-Condition-Incident-Ambulence; Medical-Condition-Incident-Injury;

Table 4.1. Codes forming themes from the exploratory study

4.3 Study Findings

In this section we will outline the primary findings of this exploratory work. We extracted three main themes from our thematic data analysis: object-as-communication, emergency situation, and clicker-as-conversation.

4.3.1 Dog Training and Skills

Our study collected observational and interview data from the dog trainers and owners at Medical Detection Dogs (MDD) (see §3.3). By interviewing and observing the dog trainers, we learnt about existing training practices, which helped us to understand the daily interactions and challenges that form the dogs' working days. We learned that the assistance dogs and scent detection dogs that "work" at MDD differ in one important aspect from many other such training centres: the dogs are usually started as puppies, but even as young puppies live and are raised in home environments, and "come to work" during normal working hours like their human counterparts (Figures 4.1 and 4.2).

Figures 4.1 and 4.2. Left and Right: Two Medical Alert Assistance Dogs (MAADs) relaxing in their work environment. These images reflect the fact that MAADs are made to feel comfortable and enjoy a similar lifestyle to a normal pet dog in between training sessions and medical incidents. Importantly, the "no kennel" policy that the organization operates on ensures that dogs have a home-like environment in between training sessions.

Since their working environment and lifestyles can vary, individual dogs may be naturally more suited to one type of scent detection over another. Dogs are usually acquired as young puppies. Each puppy has a plan for what type of scent detection dog it will grow into: but this plan may need to change as the trainers get to know the dog and its particular strengths and weaknesses. The selection process is reminiscent of one that human children face: primary education for basics, then specialised training or trade at approximately age 16. Once the dog's personality has solidified and matured and trainers have a better idea of their aptitudes. The dogs usually graduate from basic training somewhere around age 12 months, then do more specialized training until they are placed with their new job around age 13 months.

The lack of kennels and on-site boarding is not standard practice for working dog training centres. Usually, at least some dogs are boarded. However, MDD takes the viewpoint that dogs living in normal home environments, and not boarding in kennels, serves a dual purpose. First, it affords the dogs a better quality of life. Secondly, as most of these dogs will eventually be placed in a home environment- the organisation deems it is better for them to become habituated to family living from an early age. That is, if a dog was to spend his or her whole life in a training centre kennel, it might take longer for them to make a proficient use of their skills within a home environment.

Basic Training

We had the trainers describe the various stages of foundation training to better understand the dogs' backgrounds and foundation of skills. Basic training for assistance and working scent detection dogs consist mostly of socialisation when the dog is growing as a puppy. From the carers, or 'puppy socialisers' as MDD and other assistance dog organisations call them, the puppies will learn basic obedience commands, as well as housetraining, and in general how to behave politely and safely in all sorts of situations (for example around other animals, children, traffic, loud noises, or in stores). The dogs will also learn *heelwork*, where they are trained to walk correctly (heel) on a lead, constantly checking in with their walker to keep pace with them, and remain in the walker's verbal control with no tension on the lead. All of this training provides a minimum foundation for any dog that will be expected to have a working career where it will need to access public spaces.

Clicker Training

Alongside basic training, some dogs will receive a foundation in *clicker training* (Pryor, 2000), which unlike the training described in the previous section, is not considered standard training for pet dogs, but rather dogs that will need to be trained for specific advanced tasks that require shaping specific behaviours. As one of the most widely utilised animal training techniques, clicker training is used with a variety of animals including dogs, horses and dolphins. It is based on *operant conditioning* (see §2.4.1) where the dog learns positive associations with the sound of a clicker, a small hand-held device that when activated creates a loud popping sound. During the study, the trainers used clicker training in the majority of sessions to dynamically guide the dogs towards specific behaviours, thus nurturing the development of specialised skills. We observed and recorded clicker training sessions, as the trainers demonstrated basic training. Clicker training can be described in at least three distinct steps:

Step 1: Reward association or "loading the click"

The first thing the animal learns in clicker training, is that the sound of a click will quickly be followed by a reward (at first, this is almost always food, but can later be changed to other rewards). This part of the clicker training process is sometimes called "charging up" or "loading the click" and involves the animal repeatedly hearing the clicker and immediately being fed food rewards to create the association that "click = treat". For example, to begin loading the click, a training session may simply look like:

Trainer: (Offers dog a treat)

Dog: (Takes treat from trainer's hand)

Trainer: (Clicks as dog takes treat)

Trainer: (Five seconds later, offers another treat)

Dog: (Takes second treat)

Trainer: (Clicks immediately as dog takes second treat)

Trainer: (Eight seconds later, offers another treat)

Dog: (Takes third treat).

When loading the click, trainers are not clicking to reward a certain behaviour, they are simply creating a positive association with the sound of the click, so that moving forward the dog recognizes it as a discrete communication of "yes", "well done", "keep doing that", etc.

Step 2: "Getting the behaviour"

This stage is introducing the use of the click to guide slight behaviour changes. For example, it can be used to first teach a dog to pay attention to scent, which is a first initial step for any scent work. To accomplish this, puppy just starting out will be given a click merely for showing interest in a scent sample. Once the dog has realised that it is being encouraged to sniff, things can progress further.

Clicking may be used to convey different meanings at different stages of training or contingent on the particular dog. For example, one female dog observed appeared to interpret a click from her trainer as an acknowledgement. Thus, when she completed an action (such as indicating or non-indicating the presence of bed-bugs in a test sample tube) she appeared to display an expectation that she was about to hear a click (perked ears, glancing at trainer), and demonstrated disappointment when she did not (increase in physical frustration signs in body language, such as tense posture, shallow breathing, and slow tail movement). In this way, the trainers are able to mimic negative reinforcement without actually harming the dog, but rather disappointing it, so to speak, with the absence of the click that the dog is trying to obtain. For example,

> (Trainer 1 (T1) has hidden a treat within the room, underneath a couch)
>
> T2: (Enters room with dog and simply stands, doing nothing)
>
> Dog: (Looks at both trainers briefly, then lowers head to the ground and sniffs)
>
> T2: (Click)
>
> Dog: Head shoots up when hearing click.
>
> T1 and T2: Stand totally still, giving no feedback to the dog, waiting to see what the dog does.
>
> Dog: After a few seconds, lowers head to the ground again and looks towards couch.
>
> T2: (Click)
>
> Dog: Continues sniffing, now moving towards couch.
>
> T2: (Click when dog takes step towards the treat)
>
> Dog: (Having located the treat, eats treat)
>
> T2: Clicks and praises verbally.

This is an example of "hot and cold" clicker training for a search dog. The "hot" is a click, which lets the dog know they are on the right path or doing what the trainer wants; it's encouraging. The "cold" is an absence of stimuli, in this case when both trainers simply stand looking at the dog. This encourages the dog to continue guessing what the trainers want, in this case, to continue following the scent. Once a dog knows that a click is affirmed, and that the training "game" is to offer different behaviours until one is encouraged meaning they will soon be able to learn more complex behaviours.

Step 3: Testing the behaviour

This stage entails raising the standards of precision and only clicking when the animal does things 'just right'. We found watching the training sessions like watching two people play a game of hot or cold. So in this analogy, the clicking noise can serve as a way for someone to say 'warmer', i.e. “you are getting closer to the desired behaviour, but you have not yet done the exact desired behaviour so keep trying”. When the dog finally accomplishes the ultimate behaviour the trainer was looking for, they may get a “jackpot” reward that is either a larger-than-usual amount of treats or a game with their favourite toy.

If clicker training is done in small enough intervals of behavioural change (e.g. first the dog just glancing at an object, then holding the glance for a few seconds), it can be used to teach behaviour that would be very unlikely for the animal to do spontaneously (e.g. Staring intently at an object for more than four seconds). The following extract from a training session with a young scent detection dog in training, a male black Labrador Ulysses illustrates the back-and-forth dynamic nature of clicker training in this context. Here, Ulysses is at his very early stages of doing click work on scent discrimination and is working with two trainers (T1 and T2) who are cooperating to interpret his performance:

> Ulysses approaches the nearest of two lined-up small plastic pots, which contains a biological sample with the scent he is learning to recognise. 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 nearest pot again (which now contains a sample with an irrelevant scent- a “blank”). T1 mentions to the T2 that Ulysses is signalling based on a prediction of the trainer’s behaviour (i.e. that they will always place the

relevant sample in the first pot), as opposed to actually signalling because he is smelling the target sample.

Subsequently, T1 replaces the blank pot with a target pot, and this time, even though Ulysses noses the target several times, T1 refrains from clicking until Ulysses has 'held' his attention (nose to the pot) a bit longer than before. Then Ulysses 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’ behaviour, Ulysses is then presented again with a blank 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 nearest pot now contains again the target sample. Ulysses sniffs the pot but T1 waits until he sniffs it again, this time longer, before clicking.

T1: *“I'm looking for a difference of behaviour [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 Ulysses 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 the target sample and gives it a distinct sniff, holding his attention half a second longer than he had for the blank, and immediately gets a click.

This last click indicates a “breakthrough” moment where the dog is beginning to realise that pots with a certain type of smell should get more attention than others. Building on this, a dog can soon learn to distinguish (and indicate) for particular smells. Once the dog has learned to distinguish a particular smell, trainers are able to get the dog to alert when the smell becomes present. The next section presents more details on how dogs are trained to alert.

Figure 4.3. Ulysses approaches a scent pot placed a stainless-steel metal strip. Here he is shown inhaling the scent of the pot to determine whether the target scent is present or not. This is an example of “yes or no” scent indication, where a dog is presented with a single sample and expected to either indicate the presence of a particular smell, or not indicate to say “no”.

4.3.2 Alerting in Assistance Dogs

Once the dog has learned to distinguish a particular smell via methods like those described in the passages above, trainers are able to get the dog to indicate when the smell becomes present. For dogs working in the lab, this is always called indication, and the dog will be either distinguishing between samples or indicating the presence of a scent in particular lab samples in a controlled way. On the other hand, if the dog learns scent detection so that they can be paired with a vulnerable person that has a medical condition, to become their Medical Alert Assistance Dog, the dog’s indication or detection of a smell is called an *alert*. An alert is important because a medical issue (and thus smell) could come about at any time, so the dog needs a unique behaviour that will get the attention of its handler when they want to indicate the presence of the smell.

We saw that different dogs alert in different ways. Some dogs may indicate or alert by sitting and staring at where they detect the scent. Others are more physical alerts. For example, where the dog 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 relatively passive alert (like staring) and get progressively more attention-seeking until they perceive that their human has acknowledged their alert. Once they have acknowledged the alert verbally, the handler 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. However, we have seen how recognising the dogs' alerts could still be a problem for the human. Occasionally, a dog's owner could not distinguish between when the dog was alerting and when the dog was merely spontaneously performing a similar behaviour, an issue we will discuss in the next section.

Alert Ambiguity

The trainers we spoke to identified problems that come up with the alerting process. As many of the alert behaviours are also behaviours that could come up in daily life, it can sometimes be challenging for handlers to know the difference between their dog alerting and their dog "acting like a dog". At times these behaviours can appear ambiguous to anyone who is not a dog trainer, that is, anyone not proficient in interpreting canine body language. The trainers are extremely attuned to reading canine communication, but once the dog is placed in his real-life partnership, it can be harder for the new human owner to read the dog's body language as successfully as a trainer might. For example, if a dog is trained to alert by lying down, the owner of the dog may not always be able to tell if the dog is lying down because he is tired or because he is alerting. Whereas a dog trainer would likely be able to tell from other subtleties of the dog's body language, the owner may not be able to, and so they could miss the alert or think the dog is alerting when he is actually just resting. Thus, even when a dog is aware of the smell he is trained to detect (e.g., dangerously low blood sugar), and thinks he is alerting in the manner he is supposed to, the warning could be missed due to the handler missing or misinterpreting the dogs alert. Depending on many factors, this can cause MAAD owners more trouble than others.

Eliminating Alert Ambiguity

To alleviate this issue of interpreting when a dog is alerting and when he is not, some MAADs are taught to retrieve a generic special object, called a ***bringsel***, as a form of alert. This practice is becoming popular within scent detection dog-training. A bringsel is a distinct tube or "U" shaped object that may hang from a dog's collar or be kept somewhere designated around the owner's house. The practice originated in the world of search and rescue dog training, where dogs were trained to come back to their handler holding the bringsel in their mouth when, and only when, they had found a missing or injured person. The distinct action of taking the bringsel in their mouth would therefore unambiguously signal that the dog has found something and the handler could therefore be sure of what the dog meant. While a non-specialist might miss subtle expressions of canine body language, they are able to interpret what the dog means if the dog only uses the object in very specific circumstances. Medical Detection Dogs has combined the use of a bringsel with the practice of having a dog fetching a blood-test kit. Both are physical objects with distinct meaning, but the blood test kit has the added benefit of being of immediate use for the person that now needs to test their blood sugar level in response to the dog's alert. This approach is deemed to kill two birds with one stone.

Figure 4.4, 4.5. Dogs using bringsels to alert. The top left dog is a search and rescue dog that is wearing an orange bringsel on his collar, so that they can quickly grab the bringsel in his mouth if he wants to signal to his handler he has found person. The top right dog is a Diabetes Alert Dog that is using a bringsel to indicate to his handler, a young girl, that her blood sugars are too low. *Sources: https://romp-roll-rockies.blogspot.co.uk/2016/04/a-symbol-from-times-past.html and http://clickertraining.com/a-nose-for-danger-diabetic-alert-dogs-save-lives*

4.3.3 Other Outstanding challenges; Emergencies

We interviewed the participating trainers about the various outstanding challenges that scent detection dogs and their handlers face. One thing we asked trainers was a general leading question of "What are some general issues you face daily?" Their responses reflected themes discussed above, such as alert ambiguity. However, they also told us of a major issue that can come up when an owner of a MAAD is alone when an emergency occurs. We learned that usually, when an alert dog is able to detect an oncoming emergency for various conditions (whether it is a seizure, allergic reaction, breathing restriction, or diabetic coma), the dog is able to alert their owner in time for the owner to respond or seek appropriate help to prevent the emergency. Prevention is always the goal. However, importantly, the trainers mentioned to us that sometimes things do not go as planned. Owners can miss or misinterpret an alert, or it can also happen that the owner realises what the dog is warning them of, but is simply already too incapacitated to react in time. When no other humans are around, this leaves the dog helpless. We were also told that besides the obvious immediate danger of the owner that should be avoided, over time these sorts of incidents can shake the assistance dog's confidence and harm the overall partnership.

4.4 Discussion

The first study provided a starting to point to learn about scent detection and medical alert assistance dogs; their skills, training, challenges, and relationships with their handlers. Here we discuss some of the findings from this initial study.

4.4.1 Multi-species Communication and Partnerships

Our initial findings highlight that designing for assistance dogs means designing for a human-canine intimate partnership as a unit. During this work, it has been clear that the working canines and their human handlers have dynamic, intimate relationships and ways of communicating. The training sessions we include here are just examples of dozens of sessions each trainer will have with a dog to build a strong rapport and teach the dog to be an effective working dog.

From this initial work, we reject the assumption that any interface designed for dog use will not closely affect the dogs handler as well, given the closeness of this working relationship. Working dogs do not exist in a bubble, they are usually being guided and motivated by their human handlers.

4.4.2 Potential to Build on Existing Practices

This study illuminated how complex the communication interactions between humans and working canines truly are. These human-canine partnerships maintain 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 and therefore compromising their alerting performance, particularly in critical situations. As such, any technological intervention aiming at supporting the alerting work of the dog needs to be embedded in existing practices and the tools utilised within them (e.g. by developing something similar to a technologically enhanced bringsel). Due to the complexity of the training process based on long-term conditioning and associations, we considered that at least initially, any new canine interface system that is developed for extensively trained scent detection dogs should integrate within existing practices, for example, by embedding new functionalities within existing objects already in use (like bringsels or diabetic blood test kits). One such possibility that was seen was the opportunity to technologically enhance the aforementioned bringsel objects that are already being used so that it could perform additional functionality (such as making remote contact for help in emergencies, or activating additional systems in the home when the dog uses it). Similarly, we saw an opportunity to leverage the widespread use of the clicker as a form of training feedback as a potential feedback for any canine interface.

4.4.3 Methodological Implications

During training sessions observed during this study, we noticed that the trainers often 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 ability to be able to question participants easily during contextual inquiry activities results in more complex data and could potentially lead to more accurate requirements for animal systems.

In addition to leveraging talk-aloud methods during sessions with trainers, we began to see during this study how we might include dogs directly in the research. While most of this study included observing routine tasks the dogs were already doing with their training, we saw that in subsequent studies we would need to include them directly in the "conversation" to see what sort of designs might be successful or unsuccessful for the dogs themselves. We foresee communication barriers (how does a dog tell you when it "likes" something?), but also the potential to combat such barriers by using real-time translation through specialised trainers who are able to interpret the dog's reactions directly, and/or reflectively when analysing video footage. Rather than "training" a dog how to use something, we see that the dog trainers will need to effectively communicate to the dog how to do something via complex interactions, including the standard clicker mechanism practice to bridge communication gaps.

4.5 Chapter Summary and Discussion

During this study, we identified themes of a dynamic, complex communication and relationship between trained scent detection dogs and their handlers. We learned about existing practices of click-for-feedback in dogs and using unique distinct objects (bringsels or blood-test-kits) for a specific meaning. And, importantly, from this initial study, we **identified the need for an emergency alarm system** that a dog could trigger to call for help. This important finding from the study guided the rest of this thesis work. Moving into Study 2, we wanted to find out what such a system for canine remote calling might look like, so we needed to seek more information on potential users of such alarms, that is, owners of medical alert dogs.

5

Design Study: In-Depth Interviews

This chapter describes the second study, where, following from the first exploratory study in which we identified a need to support assistance dog partnerships during emergencies, we further investigated these needs by interviewing members of such partnerships. Here we describe the study design, findings, and discuss the implications from the findings for designing a *canine emergency communication system.*

5.1 Motivation

For this study, we wanted to understand as much as possible about the dynamics and challenges of Medical Alert Assistance Dog (MAAD) partnerships and the issue of emergency situations they face described in §4.3.6. In order to identify ways to potentially support MAADs with a technological system, our aim was to build a picture of how different MAADs alerted their owners during incidents, and what forms different emergencies take across different partnerships. We knew that there are a variety of conditions that MAADs support, although most are Diabetic Alert Dogs (DADs). We were also aware of a variety in the type of dogs MAADs are (in terms of size, breed, personality, etc). We suspected that all emergencies might not manifest in the same way, or elicit the same response from different dogs, but needed to do further investigation before moving on to designing an initial system.

5.2 Research Approach and Methodology

We selected six MAAD partnerships to participate in a series of in-home interviews. These assistance dog partnerships were identified and recruited through the same training organisation as our first study, Medical Detection Dogs (see §4.3.1). The six participant partnerships were interviewed on multiple occasions both at the assistance dog training centre and in their own homes. The owners informed us of the dogs' routines and behaviours and we also observed the dogs directly during training sessions and executing routine tasks.

5.2.1 Participant Selection

The partnerships selected to participate in this study were chosen based on availability, interest, and in order to reflect a variety of different medical conditions (see §3.2.1, Table 3.2 for a complete list of participants). Medical Detection Dogs (MDD) primarily trains Diabetes Alert Dogs, which support individuals with brittle Type 1 Diabetes. However, they do support other types of conditions, such as Addison's Disease, Postural Tachycardia Syndrome (POTS), Ehlers Danlos Syndrome (EDS), Congenital Central Hypoventilation Syndrome (CCHS), and a variety of severe allergies. Ideally, we would like to select a participant with each supported condition. However, due to the small numbers (in many cases 1-3 total) of the more rare condition partnerships, this was not possible. There was also a limitation within the scope of the study, restricting any participant partnerships to those that were approximately 3 hours or less travel time from the training centre, which reduced the number of partnerships we could select from. Twenty partnerships were approached through email to see if they were interested in participating in the study, and twelve responded in a timely manner confirming interest. However, only six were selected to participate based on the factors described above and schedule availability.

5.2.2 Data Collection Methods

Semi-Structured Interviews

Conducting interviews is a data collection method that allows researchers to obtain rich and descriptive data (Robson, 2002). Following from our previous study, we continued to leverage multi-species ethnography as a method of inquiry. However, unlike our previous study that focused on ethnographic observation with only some leading questions, for this study we wanted a rich, descriptive, data set that was fairly consistent across all participants. Another reason we chose to collect data via interviews for this study is that interviews allow a researcher to gather historical data (Seaman, 2008). Since much of the data we were interested in would involve participants past experiences, this was an appropriate method. We took a semi-structured approach because the interactive nature of a semi-structured interview allows for the interviewer to probe the participant for more information or follow a conversation thread, acting to guide the interview but not constraining in any way (Robson 2002). Given that this is exploratory research, we felt it was important to use the open-ended questions of semi-structured interviews that allow for unexpected topics to arise (Seaman 2008) (which in turn would enrich the data). In addition to having open-ended questions, we also did not always stick to a strict ordering of questions in the interviews. We used a more conversational method where the interviewer ensured that all questions were asked by the end of the interview, but was still able to follow a conversation thread if it was natural or relevant

Question Design

When designing the interview questions for the semi-structured interview, (see Appendix C for a complete question list), we kept a few things in mind. Firstly, the exploratory nature of the research. Second, the sensitive nature of the topics (all participants had at least one serious chronic medical condition. Third, the fact that we were interviewing participants directly, but also in a sense interviewing the canine participants through their humans as well. The question list was consulted with MDD dog trainers to confirm that they were appropriate for their clients.

When designing our questions, we included some basic questions that participants would be likely to feel comfortable and confident answering, such as “How old is your dog?”, “How long have you had your dog”?, and “How does your dog alert”? We also included more leading questions that would provide an opportunity for participants to talk at liberty about their lives and their pets, such as, “What is your favourite thing about your dog” and “How has having your dog changed your life?”. In addition, we also asked each partnership specifically about the circumstances that had led up to any medical emergencies that they had experienced. From this information, we were able to begin to understand the potential contexts of use of the alarm system.

5.2.3 Potential Limitations

One potential limitation of this study was the relatively small number of participants. As mentioned above, MDD only has one or two partnerships for some of the non-diabetes conditions supported, so we did not have as big a pool to select from for non-diabetes conditions as we did for the Diabetic Alert Dog partnerships. However, we were foremost interested in the range of scenarios and challenges that MAADs can face during emergencies, which do not map directly to the medical condition that the dog is trained to detect. For example, one MAAD owner with Type 1 Diabetes may present with seizures during hypoglycaemia, whilst another may present with sudden unconsciousness with no warning. Similarly, different medical conditions may present with similar scenarios. Given this, and also since exploratory research studies often deal with small numbers, we were satisfied that the number of participants of this study would yield useful data.

5.2.4 Ethical Considerations

Ethical approval was sought before conducting the study. Human participants were given a consent form to sign to cover their own participation (see Appendix B). Again as in our previous study, in addition to signing a consent form on their own behalf, the human participants also signed the same consent form on behalf of any canine participants as their human guardians. We were not aiming to ask the canine and human participants to do any sort of tasks that would pose any risk of harm. Due to the in-home and intimate nature of the subject matter, care was taken to make sure all participants were aware of what the study would consist of and were comfortable talking about their conditions in their own home environment.

5.2.5 Procedure

The study took place over the course of 6 months in 2014 and 2015. After each participant had confirmed they wanted to participate, an initial interview was scheduled at the participant's home, or in two cases, on-site at Medical Detection Dog's centre. These initial interviews were audio recorded on the PI's phone, and short-form notes were also written down during the interview. We did not video record any of these interviews because we felt it was important for the participant to be completely at ease during the interviews, and at liberty to speak and act freely without being self-conscious of a camera. While, as in the first study, the body language of the canine participant's was important during parts of the data collection process, we here relied on real-time interpretation via the human participants to describe their dog's behaviour, rather than video analyse it at a later date.

The initial interviews lasted between 45 minutes and 2 hours. Second, follow-up interviews were scheduled for all partnerships at variable times after the first interviews, depending on schedules of the PI and the participants. Second interviews also followed a list of questions and focused more on emergency situations and seeing more of the dog's behaviour as a follow-up to the introductory interviews. The initial interviews focused on building a baseline of understanding about the partnerships living environment, medical condition, and partnership, as well as the dog's particular personality and habits. The second interviews focused more on detailed issues surrounding the dog's particular training and on any non-routine medical incidents that had occurred since the first interview. Both interviews sought to understand how both human and dog responded to routine and non-routine situations. (Questions for both interviews are reported in detail in Appendix C)

5.2.6 Data Analysis

The hand-written notes from the interviews were transcribed and the audio transcript from each interview was also transcribed and divided into each leading question's subject area. Then these two sets of data were merged and analysed thematically to see what was similar or varied across the different participants, which will be described in the following sections.

Thematic Analysis and Inductive Coding of Interview Data

We applied thematic analysis to the transcribed notes and interview transcripts. Units of coding were chunks of text that were either: less than a sentence, one ore more sentences, or an entire paragraph. Boyatizis' "hybrid" approach was followed as we combined inductive coding and also coding led by findings from previous research (in this case, the previous exploratory study).

The thematic analysis process consists of three stages (Boyatizis, 1998):

Stage I: Deciding on sampling and design issues;

Stage II: Developing themes and a code;

Stage III: Validating and using the code.

Stages I-III were conducted as follows:

1. In **Stage I** for developing codes inductively it is recommended that subsamples of the analysed material are selected and coded first (Boyatzis, 1998), but in exploratory research this may not be possible, as was the case here, so codes were developed the whole data set in this case.

2. **Stage II** consisted of closely examining the data and building up codes into themes. In this hybrid approach, inductive coding was applied, but themes from the previous study (Chapter 4) were considered, but no formal code book was created.

The codes were developed in the following way:

Step 1: Units of coding (chunks of text) were marked and assigned a code (code generation) After initial passes, codes began to be re-used.

Example: Code: positive-emergency-avoided

"…we do love it when we can say **crisis averted**, don't we [dog name]?"
"…**didn't** even **need to call**…."
"So pleased when I **don't have to bother** anyone."

Step 2: The code refinement. All codes were double-checked to ensure that the units of analysis marked with the particular code fitted the label and the code definition.

Step 3: Merging the codes. Some units of coding were coded with more than one code, during this process the codes were merged and description updated.

Example:

Old code	Old code	New code
DogRelationship-Positive-FeelSaferWith	DogRelationship-Positive-Trust	DogRelationship-PositiveImpactF

3. In Stage III the codes were validated. In this case validation was by research collaborators that were familiar with the research and with canine behaviour and assistance dog training. Samples of

units of coding and the code mapping was given to the validator who had not earlier coded or developed codes, then a comparison was drawn, and any discrepancies between original codes and the validation codes were discussed, and changes made if necessary.

Past-Event Validation

In considering the reliability of such incidents, we noted that incidents had already been verified by MDD itself, since the application process for an assistance dog is rigorous an in-depth. Applicants have to keep careful data of all medical visits, treatments, and emergencies in the follow-up to their application. This data is verified by health records to disallow applicants to exaggerate the extent of their health conditions. Thus, reviewing our interview data, we verified individual incidents with the dog trainers, who confirmed that the stories matched up with the applicant's original application data and from what they had also experienced as a support for the partnership.

5.3 Findings

In this section, we will present an introductory profile for each partnership that describes their medical condition, home environment, and specifics on the MAAD's training and relationship with their handler, as well as how emergencies are responded to at the time of interviewing. Through these participant profiles, we see that each participant partnership of dog and human have very distinct details unique to their situation. However, we also see themes emerge, such as a fear of medical incidents and what happens to their dog during such potential incidents.

Dog/Handler	Dog Breed / Gender	Handler Medical Condition	Lives With?	Night emergencies or Day?	Interested in device for support?
Sebastian/Caren	Labrador, M	T 1 Diabetes	Alone	Both	Yes
Merlin/Catherine	Labrador, M	T1 Diabetes	Partner, pet dog	Both	Maybe
Nemo/Yvette	Mini-Poodle, M	Nut allergy	Partner, children	Day	No
Goliath/Tim	Labradoodle, M	T1 Diabetes/Wheelchair	Partner	Day	No
Evie/Karen	Labrador, F	T1 Diabetes	Alone, pet dog	Both	Yes
Ray/Jessa	Labrador, F	CCHS	Parents	Night	Yes

Table 5.1. An overview of each of the participating partnerships situational data derived from the interview data (health condition, home environment, time of day medical incidents usually occur, and if they would be interested in having an emergency alarm system to support their dog)

5.3.1 Caren and Sebastian

The first client participant, Caren, was an adult female with Type 1 Diabetes. She had a long-established partnership with her dog, Sebastian, an unusually large and tall male black Labrador. Caren had impaired awareness, meaning she could not always notice signs of impending hypoglycaemia. Thus Sebastian's warnings are especially important to her as they can be the difference between a manageable situation and a being in a coma in a great deal of danger. To add to this importance, Caren lives in a flat alone, with no one else around to help during an emergency, making prevention critically important. Caren has been diabetic for over twenty years. Her parents used to visit her every night to check in on her, but they have now passed away so her siblings and friends check on her instead when they can.

Caren has had Sebastian from a puppy. She was on a waitlist for years for Medical Detection Dogs to be taken on as a partnership to do training with Sebastian so that he could reliably alert her low blood sugar. Sebastian is trained to alert to Caren being both too high and too low in her blood glucose levels. Caren told us that Sebastian is more calm when she has low blood sugar rather than when she has high blood sugar: *"I don't really want to be too high…The thing is when you're low* *and I drink Lucozade and I get myself sorted, he's quite calm then. But when I'm high, it takes longer for it to come down and he's more agitated with me. I set my alarm for 15 minutes to re-check. Because I forget, if I go too low, I'll forget. So when he alerts 5 or below, I set an alarm. The machine may be 20 minutes behind."* Sebastian is also trained to recognise sudden drops in blood sugar. Caren also told us that *"[Sebastian will] alert my brother, who's also a Type 1. He's never been trained to do that, just does it."*

However, Caren has in the past expressed doubt as to whether Sebastian was always alerting accurately. In response to her concern, the Medical Detection Dog trainers had observed the dog's behaviour throughout a visit to the training centre. They determined Sebastian was alerting consistently correctly, with what they perceived to be 100% accuracy. The issue is that sometimes Caren was already experiencing unawareness due to the blood sugar drop, and was not "catching" his alerts. Caren told us that this has improved over time and she is now better at interpreting Sebastian's alerts.

During our first interview, I noticed that Sebastian appeared to be very attuned to Caren, frequently looking in her direction or walking over to her and visibly sniffing the air with his nose. At one point, we went outside to let Sebastian stretch his legs and free-run. Here I observed that even when Sebastian was outside playing with other dogs, he would run back every few minutes unprompted, sniff the air around Caren, then return to playing. One of Caren's 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.

When asked about previous emergency incidents, Caren reported that when she missed her dog's alert and slipped into hypoglycaemic coma, the moment she woke up the dog was right by her side, "…*staring at me worriedly*". She also reported waking up with bruises on her arm consistent with Sebastian nudging and pawing her, presumably trying to wake her up. Additionally, medical response teams reported that when they found Caren unconscious, Sebastian was lying by her side. From this information, it was thought that Sebastian routinely makes an extended effort to wake his handler up and then does not leave her side until she either wakes up on her own or someone arrives to help.

We asked Caren if there were any kind of device she could envision that would help in her situation. Caren responded that she lived in daily fear of going into hypoglycaemic coma and not having someone find her in time, and therefore had been exploring options for some sort of alarm that her dog could use to alert friends in this situation. When asked if she thought such a system would be most effective if it was portable or based in a home environment, Caren reported feeling particularly great fear going on walks, because there might not be any way for someone to find her if she went into coma. She therefore felt that the system should be wearable by either the dog or human and specifically requested that such a device would be lightweight and as small as possible.

5.3.2 Catherine and Merlin

The second participant partnership consisted of Catherine, an adult with Type 1 Diabetes, and her male Labrador, Merlin. Catherine lives in a household with her partner, as well as Merlin, and another pet dog, a spaniel named Charlie. Catherine is a professional diabetes care nurse and thus especially knowledgeable about Diabetes. Catherine’s diabetes is difficult to manage and she has an insulin pump fitted to her side, to regularly push insulin into her system, but she has to activate it herself.

Catherine applied for a DAD and was placed with Merlin, who had been trained by the organisation since he was a puppy to become a MAAD. Merlin is described by his trainer as a very straightforward, willing dog, without many complications and he is not particularly anxious. We asked Catherine about her life before having Merlin. Prior to her placement with Merlin, when

Catherine was unconscious alone with the dog in the house, Catherine's pet dog was heard by neighbours, howling and barking uncharacteristically.

We asked Catherine to describe Merlin's alerting behaviour. She said, *"If Merlin thinks my glucose level is below 4.5, he'll put his paw onto my knee, and if I kind of ignore that, he'll be a little bit more forceful, and actually try to get his face in front of my face, so actually my attention is drawn to him, and he's so focused on me, he will not leave me alone, until I take action."* Merlin alerts glucose levels above 12 as a high. During the day, Merlin alerts by rearing or jumping up and staring. At night, he paws, nudges, and will jump on the bed. Catherine's pet spaniel does not interfere with Merlin's alerting. When he sees Merlin alert he runs for the treat bag because he knows he's going to get a 'secondary' treat. Merlin does a *kit fetch* (that is, his alert consists of fetching the blood test kit) on verbal command only, as Catherine is concerned about what would happen if he couldn't' find the kit and therefore wants a strong alert that doesn't involve the kit. However, Catherine told us that on one occasion she missed a normal alert and Merlin escalated and fetched the kit to get her attention, effectively using it as a communication tool on his own.

Catherine experiences unawareness and unusual behaviour when she has low blood sugar. *"Merlin's really important, I don't have any awareness of blood glucose levels so he can actually alert me before they become too low and I become unconscious."* Catherine told us a story as an example of the strange behaviour that can occur due to awareness issues: *"My mother tells the story of when I was a teenager, I checked her bloods and went to go get juice out of the fridge. Instead of getting juice, I poured diet coke and juice together into a glass and left it sitting there."* This is an example of being conscious but not aware due to hypoglycaemia.

Prior to Merlin, Catherine had 2-3 unconscious emergencies per month. She tested her blood sugar levels 2-3 times an hour to try to prevent any episodes. Since Merlin, in 10 months she has experienced none. Speaking to how owning Merlin has changed her life, she describes: *"I can now* *go out. I will go away; I'll go to conferences. Most importantly I can sleep at night, without having to wake up. I can go to bed knowing that I'm going to wake up either when my alarm goes off in the morning, or when [Merlin] jumps on my bed. "[*Merlin's trainer*] knew I had an issue in the night, so she would wake up in the middle of the night and train Merlin. 3 o clock in the morning, she'd set her alarm, get out one of the sample pots. So now he's good at night."*

5.3.3 Yvette and Nemo

The third partnership was that of Yvette and her male toy poodle, Nemo. Nemo is a peanut detection dog. Yvette has been allergic to nuts since childhood, and the allergy worsened with age until it became life-threatening. Yvette recalls her first serious reaction to nuts: *"A few years ago, whilst on a business trip to China, I had to be hospitalised after eating nuts by mistake. This was my first experience of an anaphylactic shock, and just three weeks later, I was back in hospital after a similar episode at a festival in Germany."* Yvette was immediately referred by her GP to an allergy clinic, where she was diagnosed with a severe allergy to peanuts and other common nuts in Britain. When it comes to managing her condition in public, Yvette found it difficult to be perceived as "high maintenance". *"People often perceive you as overreacting or being difficult,"* she said, worried that without precautions, she is more likely to come into contact with nuts. Shaken from both close-call experiences, Yvette was desperate for a way to minimise the risk of further reactions

Yvette approached MDD and they trained Nemo for her as a nut detection dog. Nemo is trained specifically to search environments for even the slightest trace of nut. He is trained to go in ahead of Yvette into new environments such as aircraft, restaurants, or shops before Yvette enters. If Nemo finds any traces of nuts, Yvette will not enter the environment. Nemo goes with Yvette to her office every day and checks conference and meeting rooms before she enters in case a co-worker or visitor has accidently introduced a trace of nut. One reason why Nemo is tiny toy breed of dog, rather than larger breed, is so that he is "ultra-portable", i.e. can go everywhere with

Nemo easily, such as planes: *"He comes with me first, we search the area of the aircraft where I'm gonna sit and then if he indicates, then I ask to change seats, they arrange that, he searches that seat, if that's ok we stay there. And then in the hotel when we arrive he searches through the hotel room and then obviously he checks all my food. So a trip for [Nemo] is a very intense because normally [here at home] I'm only asking him to search once a day and I know it's [a blank test sample]. But on a trip, it's every meal, it's every laptop I touch".*

Having Nemo can be a matter of life and death for Yvette, and before she had Nemo, travelling or indeed leaving the house was very dangerous. In the four years she's had Nemo, he has never missed a nut trace when asked to search. Yvette's partner often plants nuts to test Nemo and maintain his training. Once, however, Nemo alerted and Yvette ignored the warning, as this story illustrates: "*We have a box of peanuts and walnuts and cashew nuts and maybe once a month [my partner] contaminates something. And we try to sometime use our own plates so that [my dog] doesn't learn that if we use the training plates. We did it at mom and dad's house and he didn't detect walnuts for the first time but they were we're not sure how fresh they were. We were in Germany last summer and this was his first trip of the qualification he gave a really weird indication in the restaurant, like he looked so confused, bless him. And the restaurant kept reassuring me that there's no way there can be any nuts or nut traces in there since they don't use it. So stupidly enough I ate it and we had the meal and we went home and everything was ok. And when I go to the bathroom I look in the mirror and my eyes were swollen and I hadn't even noticed. So there must have been something so small in there, enough for [my dog] to realize, but not enough for me to have a full blown reaction."*

We asked Yvette about the current status of her emergency incident plan. If Yvette does have an emergency or reaction, her first line of response is an epi pen. Her second line of response is a special tablet. However, if the reaction is severe enough, she will call 999. We asked Yvette if she thought any sort of device for her dog could help her in an emergency. She responded that if she did not have her partner or Nemo was less accurate, such a device could be life-saving. However, for her current circumstances, with a support system in place and an extremely accurate dog, she did not feel she would become in an emergency situation where she could not at least dial 999 before her reaction got too serious.

5.3.4 Tim and Goliath

Tim is a gentleman in his 50s who has Type 1 Diabetes and is confined to a wheelchair due to complications of diabetes. He and his partner, Jeff, and assistance dog, a Labradoodle named Goliath, they live in a one-story bungalow in a new build area. Since Jeff and Tim are both retired, Jeff is able to assist Tim on a daily basis with household tasks and care of Goliath. They describe themselves as active members of the assistance dog community and indeed have many large photos of their past and present assistance dogs displayed prominently on their wall. They are motivated to participate in this study as they know many friends and members of the community that they think would benefit from such technology. In conversations with them they are both very focused on the issue at hand – the dog, the training and the user of the alarm.

Tim has had Type 1 Diabetes for many years and Goliath is his third assistance dog. Tim's previous assistance dogs were trained by a different assistance dog organisation and were not Medical Alert Assistance Dogs, but rather "normal" assistance dogs. Tim first thought to train a diabetic alert dog when their mobility assistance/canine partner's dog started spontaneously alerting when he had low blood sugar. Tim and his partner then purchased Goliath as a puppy to raise themselves under the guidance of MDD. Goliath started spontaneously alerting low-blood sugar episodes at 15 weeks old. When it is time to alert Tim of a dangerous blood sugar level he has detected, Goliath' alert is a fixed stare, and a stronger alert is a paw, which indicates to Tim he needs to check his blood levels. During an interview, when Tim's blood sugar went low, we observed Goliath watching Tim intently as Tim takes his blood sugar level, then continues watching until Tim treated himself with insulin. Tim told us, "*He always does that- he won't have it until you do what you're supposed to do. Once he's done what he's supposed to do, he expects you to do your bit."* Tim also told us that Goliath always alerts Tim first, and then alerts Jeff if Tim does not acknowledge him on his own. He alerts at night accurately, that is, when everyone is asleep but Tim's blood sugar drops, Goliath wakes up out of a sleep and wakes up Tim as well. Interestingly, Goliath will occasionally alert strangers in public or in the supermarket "*we have to tell him not to go up to all the dieting ladies!"* says Tim.

When we asked about emergency situations, Tim and Jeff expressed that they had previously trained their last assistance dog to use buttons for emergencies. They actually used red peanut butter jar lids: *"Once [Previous Dog] had learned to target and put his paw on the peanut butter lids. Then, once he had learned how to target the peanut butter lids, we started to have him target a button that was a similar size, shape and colour as the peanut butter lids"*. When we inquired why Tim no longer uses such a system with his current dog Goliath, Tim expressed that it was not because the system wasn't helpful with their previous dog, but rather because he [Tim] is now retired and his partner is also retired, so he does not end up alone at the home experiencing emergencies anymore.

5.3.5 Karen and Evie

Karen has brittle Type 1 Diabetes, and has frequent incidents alone at home, as she does not live with a partner or anyone else, just her pet Airedale Terrier, Woody. Karen's parents used to call her at the same time every evening to make sure she was ok. Since they have passed away, this no longer happens. She thus applied for a Medical Alert Assistance Dog and waited some time before being paired with Evie, a chocolate female Labrador.

Karen's incidents are usually at night, triggered by low blood sugar and they are usually in the form of a seizure. She often vocalizes during the seizure, so she is flailing, loud, and shrieking. This has frequently distressed her pet dog, Woody. When she is thrashing, she is unable to walk or grip things normally but still attempts to. *"Sometimes I will drag the phone onto the floor, it could take me an hour. Sometimes, if I [scream] loud enough, the next door neighbours do hear [and respond]."* Karen has also fallen down the stairs due to seizing so it's important for her to be away from anything she could fall down or onto in the moments before she has an incident. Prior to being placed with Evie, these incidents were frequent, as were trips to A&E. Karen would often be found unconscious by neighbours in grave danger and lucky each time to wake again. Since having Evie, these incidents have lessened. Evie will wake Karen up in the middle of the night if she detects that Karen's blood sugar is falling dangerously. Karen is then able to wake up and treat herself preventatively before the situation becomes more serious.

Karen described the wearable alarm system that she had been given to use in the past, but had not worked for her. *"They give you one that goes around your neck, I don't want to wear one of those because before I got it caught while spasming, nearly strangled myself, nearly killed myself. Then they came out and said I could have an electric bed alert. They do a matt apparently, if you are thrashing about in your bed. I said no thank you to that."*

Karen also spoke about the current alarm system she has in her home, which is not wearable but rather a phone box that sits on a shelf with a large button. *"The button goes straight to a call centre. They ask you, are you alright, do you need assistance? Its mainly for, people not like me, old age pensioners, the like. Sometimes, people call it when they don't mean to, so they ask if you are alright. But it's not easy to use for someone like me that's on the floor. Because I'm literally, jellified. And the box is on the shelf and you have to knock it down to use it. I'm hoping they can teach [Evie] to use the button, but we'll have to put it on the floor. And its downstairs and I usually go at night."*

5.3.6 Ray and Jessa

Ray is in his early 20s and currently lives with his parents and his MAAD, a female black Labrador named Jessa. Ray has a condition called Congenital Central Hypoventilation Syndrome (CCHS). He frequently has parasomnia episodes, which Jessa has been trained to respond to by waking him up so that he can correct his breathing. Due to the seriousness of Ray's condition, Ray's bedroom has been fitted with professional CCTV footage so that the family and Jessa's trainers are able to monitor the incidents that happen at night and subsequently, Jessa's responses, and Ray's responses to these incidents. We interviewed Ray along with his parents, Linda and Barry who are very involved with his care.

Ray is a young man that, due to his condition, has lived his entire life being observed and worried over. He is passionate about long-distance running. His parents are scared to leave the house when he is awake, but unable to leave the house at night due to the danger of his condition. Ray's mum Linda says "*The worry when we are away! Well you know any time we are out it's a stress, it's a real worry.*" Ray sleeps at night hooked up to a special machine that sounds a loud alarm if his breathing becomes dangerous. However, this loud alarm does not wake up Ray as he sleeps through it. To combat this, Jessa's very specific job as a assistance dog is to wake up Ray when she hears the alarm go off. While Ray may sleep through an alarm, it is harder for him to sleep through a full-grown Labrador pawing at him and nudging him. While this does often wake up Ray, sometimes it is not enough. Since Jessa cannot always wake up Ray by nudging him or jumping on him, Jessa has been taught to hit a Talking Tile button to create further noise to wake up Ray. This Talking Tile has the recording sound of Ray's dad urgently telling him to wake up. In his sleep state, this sound is much more successful in waking up Ray than the sound of his machine's alarm or even Jessa herself pawing him. In the two months prior to Ray's first interview, Jessa had triggered her existing button device 50 documented times, and of those Ray was woken up by Jessa 29 times. Linda said *"It's been a gift and a relief, having Jessa. I will still wake up if I hear her thrashing about to wake him up, but I can stay in bed and hear if she's woken up Ray and it's sorted itself out. That's huge itself, that I can stay in bed."*

However, since this 'wake up rate' is not 100%, Ray and his parents are eager to see if a new system can result in a higher wake-up rate, and if not, to have the functionality that Ray's mother can be called and texted. Presently, the Talking Tile button is creating noise, which sometimes wakes up Ray, but the noise recording is limited to one minute because the device is not configurable. The button is also not large or robust, so when Jessa, a full grown Labrador, hits it exuberantly, it goes flying off its mounted position.

Also, there is another issue with Ray's current set-up with Jessa: Importantly, since Jessa is only awarded if Ray wakes up, Jessa is currently not being rewarded many of the times she is doing the correct behaviour (pressing the button). This is resulting in her becoming less and less interested in the button over time, as she is not being re-affirmed that she is doing the correct thing by hitting the button when he does not wake up. To solve this issue, the system either needs to successfully wake up Ray in more cases, or automatically reward Jessa (with an auto-dispense treat releaser).

5.4 Discussion

The themes that emerged from this study allowed us to move toward understanding the potential context of use of a potential device that would support emergency situations for MAADs. Here we discuss some of these themes.

5.4.1 Types of Emergencies and Canine Responses

In reviewing the data from this study, we found that medical emergencies that MAAD owners and their dogs face 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: This first level is a sort of “crisis averted” level. No outside help is required because here no emergency arises: the person does experience a medical episode or incident of some sort, but the assistance dog is able to assist them successfully to such a degree that *no outside help is required*. For example, in one of our participant partnerships, we saw that Tim has in the past been 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 Goliath is able to tug the wheelchair over the bump for Tim, so Tim is not stuck and does not need the assistance of another person. This is an excellent example of a dog helping a human through a situation that might otherwise leave them needing another person’s assistance. 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, Catherine told us that her dog Merlin alerts her of dropping blood glucose levels. Catherine 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, Catherine is able to respond to the potential medical emergency before it degenerates such that outside help is required. Before she got Merlin, she often had episodes that required emergency services or a visit to A&E. However, with Merlin, she is often able to successfully prevent ever reaching that point because the dog warns her in time to avoid an emergency. The implication for this level of emergency is that a device or system is NOT needed.

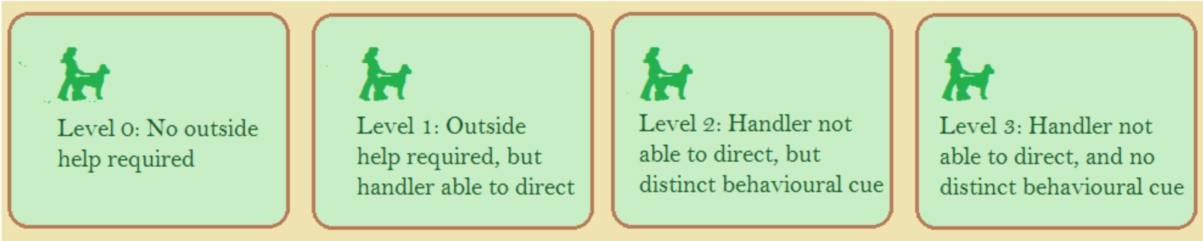

Figure 5.1. There are three general levels emergency that an assistance dog may face when alone with their handler, ordered from least challenging to most challenging for the dog to respond to. Note these are not ordered by the seriousness of the medical emergency for the handler, but rather the difficulty for the dog to respond by using an interface to call for help. At level 0, there is some sort of medical emergency, but importantly, no outside help is required (either the dog or handler or both is able to handle the situation). At level 1, outside help is required, but the handler is able to direct the dog. At level 2, the handler cannot direct the dog, but exhibits distinct behaviours that can act as cues. At level 3, the handler cannot direct, and also exhibits no such distinct behaviours.

Level 1: At this level of emergency, outside help is required, but handler *is able to direct dog*. For example, Tim would occasionally become stuck or experience a mobility problem when alone in his house. Unlike the scenario above, where Goliath can physically solve this problem himself by pulling a wheelchair, a situation might arise where the dog is not able to help and another person does indeed need to be called to help. In Tim's case, in the past, 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. Here, the implication for designing a potential system is that a dog would NOT be required to use the device completely "on thier own". That is to say, the dog could still be guided through or commanded directly by the person to use the system, because the handler is still an 'actor' in the situation at this point and can think "for" the dog. This is thus the lowest level of autonomy that a dog would have to demonstrate when using a device to call for help; 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: At this level, outside help is again required, but now the handler is *not* able to direct dog with commands, but rather the handler only exhibits distinct behaviours 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 Karen 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 these alarms, Karen 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, its gone...it's gone*". In this situation, Karen exhibits a behaviour she would never exhibit in a non-emergency, so trainers can train Evie to respond appropriately whenever Karen exhibits this behaviour. Similarly, Karen often has her blood sugar drop extremely fast and is unable to prevent hypoglycaemic 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 certain ways when the handler drops suddenly. The implication here is that while a dog may still be cued to operate a device, their handler is no longer able to direct them or support them with their interaction with the device. The dog will only know that they need to operate the device because they have been trained by a passive behavioural cue that could vary in its context, which will be more challenging than if they were being given a consistent, direct verbal cue. Thus the dog requires more autonomy in using a device because their handler will not be able to direct or correct their use.

Level 3: At this most serious and challenging level of emergency, outside help is required, and the handler exhibits little outward behavioural cues and becomes unconscious. This is the extreme end of the spectrum, where the dog finds itself with a handler who is experiencing an emergency and is also completely unable to direct their assistance dog or to even exhibit distinct behavioural cues. For example, Caren sometime is sitting on the couch watching television or resting, or even in her bed at night, when she goes into a hypoglycaemic coma. Here, the signals indicating an emergency requiring external help are much subtler, 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, they will have to take control of the situation and decide whether to call for help. Thus, we speculate that 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. However, this is also the case in which a dog successfully using a device to call for help may prove to have the most impact, ie be life-saving.

5.4.2 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 decision-making burden is distributed between 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 opposite end of this spectrum the entire burden of making sense and dealing with the situation is on the dog, while the human is unable to (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 emergency communication system for a dog would need to ensure that the dog is enabled to autonomously engage with and operate it. From this we posit that 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.

From this model of a spectrum of types of emergencies, we have also see 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). 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.

Thus, there are really two primary issues we see emerging from this study: First, there is the issue of a dog knowing WHEN to interact with the device, and secondly, the issue of the dog knowing HOW to interact with the interface. If the dog can learn successfully how to interact with a device (for example, barking three times to activate a device), but does not have successful training to let them know WHEN to use the device, the system may be rendered useless as the dog does not activate it appropriately or at all. On the other hand, if a dog understands he is supposed to engage with a system, but struggles physically to do so (such as pressing small buttons in a certain pattern), the design will also fail. Both issues need to be addressed in such a system for it to be successful.

5.5 Chapter Summary

In this chapter we have presented the second study of the doctoral work, in which we conducted in-depth interviews to begin shaping requirements for an emergency communication device for medical assistance dogs to use. From this study, we have identified different types of emergencies and presented these as a spectrum model in which there is an inverse relationship between how much understanding and autonomy the dog needs to have in a situation versus how much the human handler is physically and cognitively present to support the dog. Coming out of this study, we had identified different contexts of use and requirements, specifically, the requirement that a device is intuitive to use (to account for needing to be used with no human guidance). From our first study, we saw that such a device could build on existing practices of using unique objects such as blood test kits or bringsels to signify an alert, aided by using a click as a form of feedback. Collating this, we moved into our next study, our first physical prototyping phase, described in Chapter 6.

6

Design Study: Initial Prototype

In this chapter we will review the findings of the first two studies and how they informed the design for our first experimental prototypes. We will then review the findings and implications of this third study and discuss the further implications for the next design phase (Chapter 7).

6.1 Motivation

Having established a need for some sort of system to allow an assistance dog to call for help on their owner's behalf, we now aimed to explore specific canine requirements for such a canine emergency communication system (CECS). We wanted to investigate different ways it might be possible for a dog to interact with a device. For example, was it reasonable to expect a dog to activate an alarm by biting something? Pulling? Nudging (with nose or paw)? What about barking? In this study, our goal was to unfold specific requirements so that such a system could take shape through subsequent design iterations. Having discovered in our last study that it is imperative that dogs can naturally and easily interact with any device, as they may need to engage with it using varying degrees of autonomy, we now sought to discover what modes of interaction are more natural or easy for MAADs and what other modes of interaction should be ruled out as un-intuitive or challenging. We wanted to involve the dogs directly rather than use speculation so the dogs themselves could participate in the design process for a more accurate picture of what type of design would be successful in a real use context.

6.2 Research Approach and Methodology

From the previous study described in Chapter 4, we had been able to get real-time verbal explanations from the trainers on the participating dog's experiences during training sessions. We wanted to leverage the dynamic nature of the training environment, so we used *rapid prototyping* as a form of participatory design to include dogs in the process. Rapid prototyping is a helpful method in which the creation of low-cost, low-fidelity representations or versions of a proposed user interface can be presented to potential users to aid in a brainstorming, creating and testing process where potential users can feedback to designers without the initial resources spent on higher fidelity prototypes. Given a growing, but still relatively limited, body of literature about what sort of computer interfaces dogs interact with successfully, we had a lot of ground to cover, thus used many low-cost prototypes to keep the design open to many different ideas at this stage. These low-cost, prototypes allowed us to focus on the canine's experience with different basic interactions rather than the entire system experience for dog and human users.

We used this "quick and dirty" approach so that the trainers and canine workers themselves could be involved in the early stages of the design process. By quickly creating several different design options, we aimed to be able to use prototypes and materials for potential prototypes to support a dialogue with trainers and dogs on what might work and what might not. By having readily available, quickly interchangeable materials to work with, we aimed to be able to provide many different permutations for dogs to see what they preferred. Initially, seven different distinct ideas were considered which are described in §6.2.7. After discussions, this was narrowed to 5; and finally after further discussions, this was narrowed to the three types that were built. The discussions with trainers used prototypes and potential materials as talking points and designers and trainers alike could physically handle design components to facilitate design decisions. Finally, when the three different types were built, the canines were brought in as participants to see how they engaged with the prototypes in casual, unstructured sessions. During this informal testing, the talk-aloud method discussed in the first study phase was used again.

6.2.1 Participant Selection

We did some initial prototype testing with five different dogs. One partnership, Caren and Sebastian, from Study 2 (Chapter 5) continued to participate in this study as well. The other four dogs were selected from dogs at Medical Detection Dogs that were free during the study time period. The canine participants for this study are shown in the blue column on table 6.1. We had eight dogs that interacted with physical prototyping total across all studies. Two that participated in the exploratory study went on to do further lab testing (see chapter 7). Additionally, some medical alert dogs whose owners participated in the requirements elicitation (see Chapter 5) went on to do home evaluation (see Chapter 8).

Dog	**Exploratory Design Study**	**Lab Testing**	**Home Testing**
Sullivan	X		
Marla	X		
Judd	X	X	
Lady	X	X	
Sebastian	X		X
Goliath			X
Evie			X
Jessa			X

Table 6.1. Matrix of all canine participants across all prototype studies; this study column highlighted in blue.

6.2.2 Data Collection Methods

We followed the same data collection methods and protocol from our first study (see §4.2.3).

6.2.3 Potential Limitations

As with the other studies, this study could potentially be limited by the relatively small number of canine participants. The smaller the number of dogs participating, the harder it is to generalise the dogs' preferences. However, this limitation was compensated for by working directly with trainers that work with a very large volume of dogs. Many of the trainers have a long career in dog training and have worked with hundreds of dogs. Thus, when we observed a certain behaviour during our sessions, trainers were able to tell us if the behaviour was a-typical, typical, or somewhere in between in terms of their knowledge.

Another limitation was that we short-listed our initial list of interaction types due to practical time constraints of the study. So, instead of testing all of these initial brainstormed methods directly with the dogs, we narrowed down a list. During this process, it is thus possible that a mode of interaction was missed that could have been successful or informative to see the dogs behaviours and preferences. However, it is outside the scope of this work to see how a dog reacts to every type of potential interface interaction possible.

6.2.4 Ethical Considerations

Like the two previous studies, human participants were given a consent form to sign (see Appendix B). The human participants also signed the same consent form on behalf of any canine participants, which were in this circumstances given consent by their human guardians. However, unlike the first two studies, with this work we intended to have dogs interact directly with novel interfaces that they would not necessarily be interacting with otherwise, that is, we were directing the interaction. We still believed the study presented minimal risk of causing any physical or psychological harm as all dogs under all times were under the care and responsibility of their guardians (trainers).

6.2.5 Procedure

Design Brainstorming and Initial Potential Design List

The first thing we did for this study was create a "longlist" of potential designs for our new alarm system. Moving from a user-centred design and ability based design standpoint, we wanted a design that was user-friendly to a dog and took advantage of their physical and cognitive abilities. At the same time, we kept in mind the practical feasibility of each design. The brainstorming process was informed by researcher knowledge (i.e., Mech's wolf prey behaviour list in §2.4.7) and the dog trainers experience and knowledge in canine behaviour. Through co-location and unstructured discussions, a list began to emerge of different forms our system could take (Table 6.2):

Activation Type	Rationale/Basis	Photo Inspiration
Button Activation	Obvious. Universal. Buttons don't require dexterity. Buttons often used for input device for child or special needs technology users.	
Velcro – Detach Activation	Bringsels are widely used by working dogs (see §4.3.2), including assistance dogs. A bringsel attachment could be fitted with velcro (potentially conductive velcro) without drastically changing the nature of the object.	
Biting Activation	Most dogs enjoy biting and chewing; instinctive behaviour carried over from being a social predator (see §2.4.7)	
Magnet – Detach Activation	Fishing rod quick-releases use small magnets; once a certain threshold of pressure is applied, detachment occurs. Existing emergency alarms that use magnets (and when magnets are separated, the alarm sounds).	
Interlock – Detach Activation	Such as those that operate emergency brakes on cars hauling a trailer, or that people wear when operating a boat or motorbike. That is, if enough pressure is applied, detachment occurs. A bringsel could be turned into an interlock detachment without drastically changing the object.	
Stretching Activation	Most dogs are good at and can be easily encouraged to tug or pull an object (likely based on their predator instincts), which could result in activating a stretch sensor.	

Pull-cord Switch – Pulling Activation	A cord is pulled and toggles an internal switch- like those commonly found to turn on and off bathroom lights, which can in term trigger an alarm. A bringsel attachment could be attached to such a switch without changing the nature of the bringsel object.	

Table 6.2. The types of activation interaction considered for our canine alarm system.

Pruning the longlist of Designs into a Shortlist

Following discussions with trainers about these potential designs, some design ideas were ruled out prior to rapid prototyping and initial testing:

Button – A prototype where the dog applies pressure with their paw or nose (ie, a button) something was ruled out. This was partially informed from discussions from trainers and reviewing canine behaviour. Many of the dogs do not seem to find it intuitive based on the training effort it takes to get right. Canine behaviour supports this; a wolf would not push/toggle something in the wild; but they would certainly grab hold of something and tug it.

Velcro – This was ruled out by trainer and client feedback that it would be impractical; get fur stuck; and stick to other clothes.

Biting Sensor and Stretching/elastic – This was ruled out because it was thought to lack built-in feedback for a dog. For example, when you press a button or pull a cord, there is a sudden change in pressure and a click to let you know you have toggled it. However, with stretching or biting designs, there is no built-in discrete action or feedback.

After ruling out these designs, we were left with: Pull-cord detaching activation, Magnet Detachment Activation, and interlock-detachment activation.

Testing Shortlisted Designs with the Dogs

Having narrowed down to three types of activation, we moved forward to testing with dogs. We did not include canines directly to test all activation type designs because it was not practical to have multiple dogs try how that many designs, especially not in a situated context.

To test the remaining designs, we kept the interaction isolated without any situated context- for example we would just encourage a dog to engage with a type of alarm without any mock-emergency situations or advanced training. Once we had done this, and settled on the initial first versions of the design, we then did more advanced training with two different dogs. Throughout the different stages of this testing process, we asked the dogs' 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, we were able to understand not only how the dog would engage with the device, but also how the dog would learn to engage with it. Additionally, we asked the trainers about their understanding of how the system worked and how usable they thought it was. 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 improvements might need to be made.

6.2.6 Building and Testing Prototypes

Wood bases were used as stand-ins for the space that would eventually be occupied by electrical components. As all selected designs relied on the dog pulling on something, they needed to be attached to something to provide resistance. Thus metal hooks were attached to each base so that the prototype could be hooked to a wall, ceiling, or even belt-buckle. (See Figure 6.3)

Figure 6.1: Different parts of two prototypes labelled. The prototype on the left uses magnet detachment, the prototype on the right uses interlock detachment.

Foundation Hook: Allows attachment to anywhere with hook or loop.
Foundation Body (Base): Physically representing space for eventual electrical components; a 'dummy' of lightweight wood was used. All prototypes had wooden bases with rounded corners for safety and to minimize catching.
Attachment (Trigger): Mechanism to trigger the system- ie, electrical switch.
Tuggy Hook: The mechanism to attach different tuggies to the trigger.
Tuggy (Bringsel): The 'tuggy' part for the dog to actually take in its mouth- inspired by the idea of a bringsel. Since anything with a hook can be used, actual existing bringsels could be used to test with.

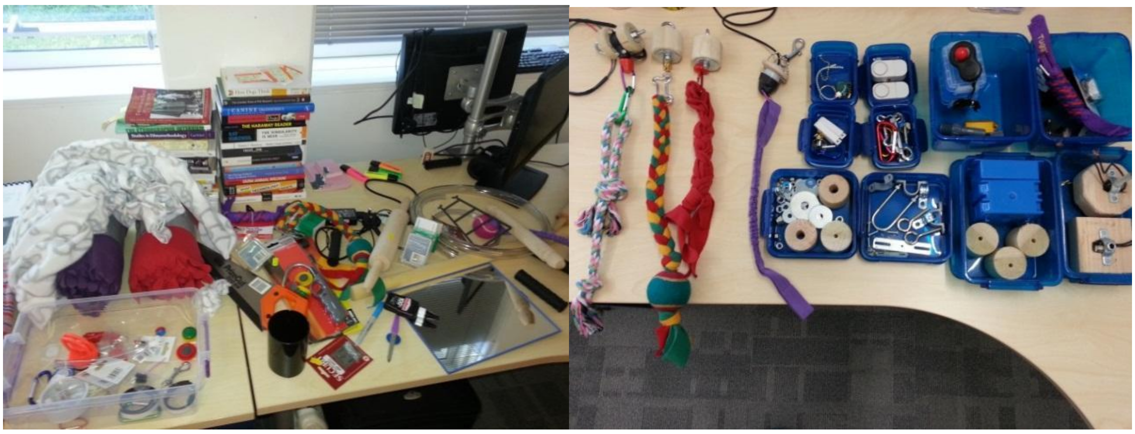

Figure 6.2. L: Initial rapid prototyping materials. R: Prototypes and more prototype materials.

6.3 Analysis

The data analysis procedure for this study followed the same methods discussed in previous sections: a qualitative, inductive, hybrid (§4.2.7, §5.2.6) approach to analysing full data sets of interview data and smaller data set of event-important video data.

As with study 1 (Chapter 4), with video we largely focused on the conversations that occurred in the video recordings. We did not use a framework for interactivity or gesture, but rather used the dog's body language and behaviours towards our various prototype testing as conversational probes to gather casual interview data with the dog trainers. This allowed us to get a merged data set that started as observation notes, video transcription notes, and audio recording transcripts, into textual data that could have the same inductive coding process applied as in previous Studies 1 and 2.

Despite following the same process as Study 1, validation played a stronger role in this study. Because we were introducing dogs to low-fidelity prototypes and gauging their reactions, often the observing researcher would make note not only of their interpretation of a behaviour, but rather of the dog trainer's interpretation. As we have started to see, the dog trainers in these studies often perform their own triangulation or validation amongst themselves, double or triple checking that their interpretation of a training session or particular behaviour is interpreted the same way as other trainers. This allowed us to have more confidence in the data, as it was not a the researcher's non-expert knowledge that was interpreting the canine behaviour, but rather creating a record of one, two or more dog trainers consensus on the behaviour.

6.4 Study Findings

6.4.1 Initial Testing with Sullivan

We introduced Sullivan, a 10-month old male cocker spaniel in early training to become a cancer scent detection dog, to the cue of "pull tuggy", which he was able to learn in a short single session.

Once Sullivan understood the command “pull tuggy” meant go and grab the tuggy with his mouth and return to his trainer, we moved a farther distance away, about 10 feet, and had him do this several times.

While in general Sullivan seemed not only capable, but also happy to participate in these interactions, in one instance the magnet attachment proved problematic. Specifically, in one interaction with a magnet prototype, we observed that after fetching the tuggy, Sullivan and the tuggy were being pulled towards filing cabinets. Sullivan seemed genuinely confused as to why his “toy” was snapping on to anything metal. Similarly, the magnet stuck to the dogs’ own collar causing him to become very playful because he could not get the tuggy off of himself. While this provided a rather comical situation, it did become immediately apparent that this would be an issue with any magnetized components, as we realised any magnet large enough to provide resistance upon detachment would also be strong enough to attract to metal components of a dogs collar.

6.4.2 Initial Testing with Marla

We also had Marla, a 5 year old female Visla, in training as a bed detection dog, interact with the hanging tuggy prototypes. Unlike Sullivan, Marla was not so keen to approach the new object and pulling it hard enough with her mouth to make it detach. Her trainers interpreted her hesitance to approach the object as not being used to seeing something hanging in such a manner. When encouraged to pull or mouth the tuggy directly by the trainer, Marla would engage, but still not as with much enthusiasm as Sullivan. When Marla finally did pull on the hanging tuggy for the first time, she let it go before it detached, which caused it to swing and hit the wall and file cabinet, producing a loud sound which she ran away from. After hearing this loud sound, she was not interested in pulling on the tuggy again, even with encouragement from trainers.

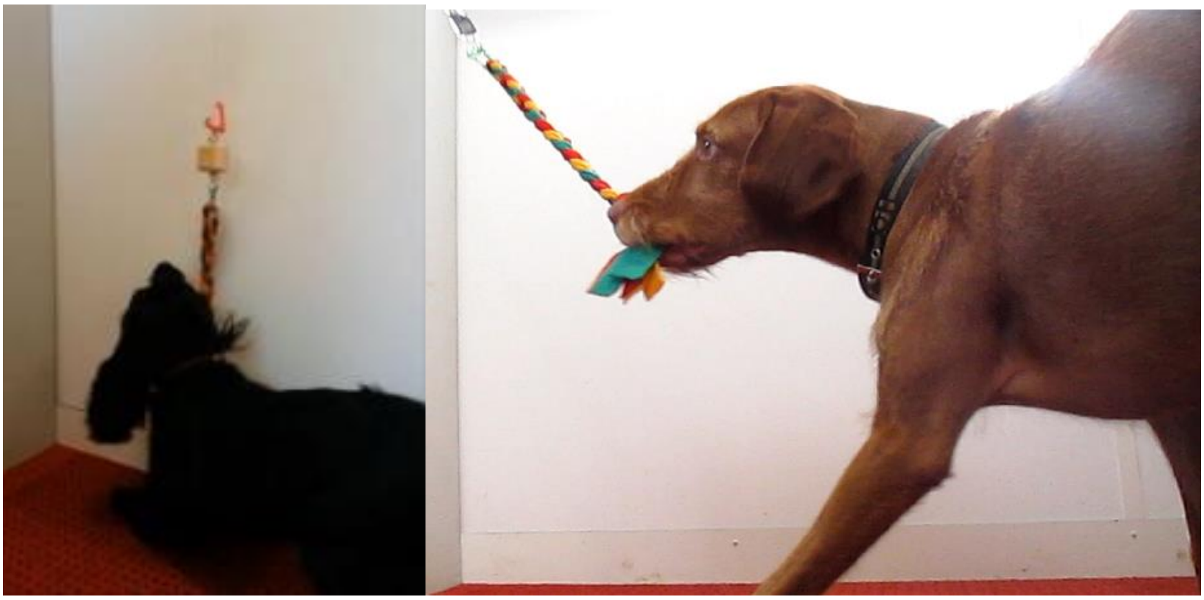

Figure 6.3 and 6.4. L: Sullivan pulling off a magnetic detachment; R, Marla pulling off a quick-release detachment.

6.4.3 Initial and Advanced Testing with Lady

After these initial sessions with Sullivan and Marla, we then did basic training with another dog, a female Labrador and Golden Retriever cross, Lady. Lady understood the command “pull pull” after one introduction to shaking a tuggy at her with this verbal cue. Thereafter Lady would without hesitation grab the tuggy with her mouth and pull vigorously. We attached different types of attachments to different places (such as “on the body”- see figure 6.6), and mounted on walls the same as Sullivan and Marla. Lady showed no hesitation whatsoever so we moved on to more contextualised training, where pulling the tuggy was cued by a behavioural cue instead of just a verbal cue. The behavioural cue that was used was the trainer falling over to the ground from either a sitting position or standing position. Every time the trainer did this, she would also say “pull pull” to link the verbal command to the behavioural cue. Within two training sessions Lady was able to pull the tuggy simply from the trainer mock-collapsing rather than giving a direct verbal cue.

Figure 6.5. Lady's trainer in a session wears one of the pull-able quick-release prototypes having attached the base to her belt loop. When cued, Lady pulls off the attachment with no issue.

6.4.4 Initial and Advanced Testing with Sebastian

We followed the same introductory training process as Lady with Sebastian, a 6 year old male Labrador. However, in Sebastian's training and testing sessions we used not only Sebastian's trainer, but also his owner Caren, a Type 1 Diabetic. Sebastian learned the verbal command to 'pull tuggy' within one training session. 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. Once he learned this command, the command was paired with behaviour, i.e. the client Caren sitting or lying on the ground suddenly (to mock a collapse. Sebastian quickly associated this behaviour with having to go over to the tuggy and pull on it, then if it detached, bringing it back to his owner on the ground. We noted that the trainers took advantage of the built-in click of the pull-cord prototype, and of the detaching aspect of the other two prototypes, as a distinct action that they could reward for during training.

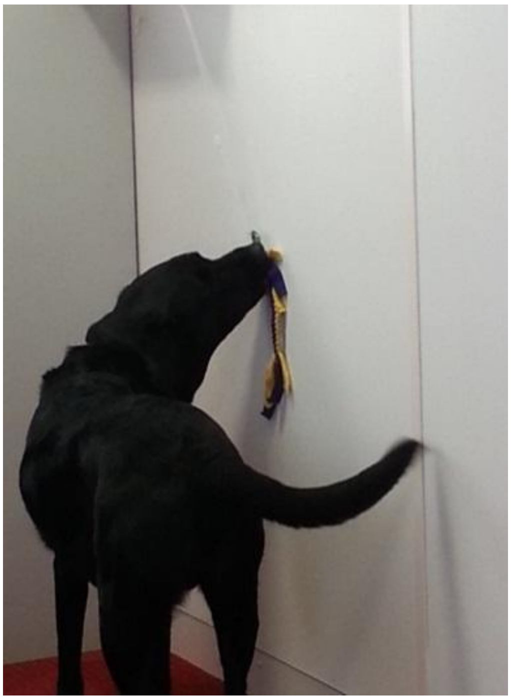

Figure 6.6: L: Sebastian pulls on one of the pull-click prototypes.

Figure 6.7. Video still from training session. Sebastian is being praised after he has correctly gone to pull on the tuggy the moment his owner pretended to collapse.

In subsequent sessions, Caren ‘collapsed’ farther and farther from the prototype, until she was around a corner from where the prototype was mounted. At this point, Sebastian no longer would go over and engage with the prototype. His walking slowed and he gave hesitant body language, staying by his ‘collapsed’ owner rather than walking away from her. However, in later sessions where the client was again in eyesight of the prototype, Sebastian again engaged with it. The trainers participating and observing this training sessions felt that that Sebastian was happy to engage with the prototype as long as he could still see his owner.

After engaging with prototypes where the tuggy became detached when pulling and also ones that did not, Sebastian seemed to want the tuggy to come detached. This was evidenced by him continuing to pull on the pull-cord prototype even after it had clicked. In fact, in one session he pulled so hard that it broke off the cord of one of the pull-cords.

6.5 Discussion

By the end of this phase, the primary canine aspect of our design had solidified, and themes had begun to emerge, which we will discuss in this section.

6.5.1 Detaching vs Pull-Click: Or both?

Within one testing session with Sebastian, it became quickly apparent that it might be best for a design that a dog pulls on to detach rather than just ‘toggle’ like a pull-cord light switch. As we have seen, part of this did come from observations of Sebastian, but also feedback from trainers. For training and reward, it is easiest to train on discrete events. A bringsel coming detached after being pulled on is far more distinct than the slight release in pressure of the toggle.

Additionally, we realised that as training progresses, at some point it would be good to test the dog with just the client who pretends to collapse whilst alone in a house. In this situation, if the dog is able to bring the tuggy to the collapsed client, the client themselves can praise the dog and reinforce this behaviour. However, if the tuggy does not detach, a trainer or helper would always have to be present for this level of training, which contradicts the use-case of the system in the first place: that the client will always be the only human present when the dog uses it.

6.5.2 Comparing Trigger types: Magnet vs Interlock?

The comical but insightful example of Sullivan sticking to a file-cabinet when carrying the magnet bringsel highlighted a weakness with this design. Further consideration and testing will be needed to address this type of issues; however, magnets were shown to be very useful with respect to the requirement of customisability, in that it is easy to change the size, shape, and strength of the connection when using magnets. For this reason, we did not want to rule them out just yet.

Similarly to the magnets, the interlock mechanism afforded clean detachment, but without the problems posed by the magnet; however, interlock mechanisms are much less customisable and the ones we were able to find did not provide nearly as much resistance as the magnets did, making it too easy for the dog to pull off. Again, further design solutions need to be explored; but both designs still seem promising as the canine participants were able to quickly learn to engage with it.

6.5.3 Proximity and Portability

We concluded that for dogs like Sebastian, who are hesitant to have their owner out of their sight in a stressful situation, it may be a requirement that the alarm trigger is not out of the line of sight of his owner when they collapse. Following our session with Sebastian, based on the trainers' assessment, we concluded that he probably wanted to be able to keep an eye on his owner as he was used to trying to wake her and watching over her, waiting for help to come 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 hypothesis in the previous section that the device needs to have some level of portability; even if the client only uses it within their home.

6.5.4 Types of Tuggies

Physically, bringsels can vary in size, diameter, length, material, attachment type. There are two main types of top attachments: slide-through and clip. In discussions surrounding bringsels, as we have seen in Chapter 4, one trainer mentioned that the training centre used different sizes and types of bringsel at different stages of the training. For example, a young dog at the early stages of his training might use a very large, soft, toy like bringsel that is appealing and inviting to take in the dog's mouth. Then the bringsel would progressively be switched for harder and smaller varieties until the dog is using the type that is optimised for long-term use.

6.6 Chapter Summary

At the end of this study, we had fine-tuned our initial prototypes into one specific model, based on our initial testing. In the next chapter we will describe the initial high-functioning prototype, which was designed based on the results of the first three studies. We will then describe the results of our lab testing and home testing with the system.

7

Lab Testing with a High-Fidelity Prototype

In this Chapter we describe Study 4, in which, using Study 3 to inform our prototype design, we implemented a functional prototype and conducted user testing with both human and canine users in a lab environment. Here we describe the study design, findings, and implications for this research phase as they informed our final study, in-home deployment testing, described in Chapter 8.

7.1 Motivation

Study 4 focused on the canine-specific requirements of the system and by using an adapted method of participatory design in which potential dog users interacted directly with a variety of low-fidelity prototypes. After this study was completed, many different modes of activation had been considered that may work well to form the basis of a canine alarm interface. By the end of the study, it was determined that a bite-and-pull (or B&P) mode of activation would be used for this system. The B&P mode of activation uses a detaching mechanism to allow a dog to follow a natural instinct to bite and pull an object, whilst also building on existing practices of working and assistance dogs using bringsel objects to communicate with their handlers. Following from this, this study aimed to take this low-fidelity bite-and-pull prototype and, through an iterative design process involving canine and human end-users, turn it into a functional, high-fidelity prototype.

We did this by considering both canine and human user requirements and the context of use based on our findings from Chapter 5, building on the themes that emerged from that work to inform further iterations of the prototype. We wanted to establish a high-fidelity prototype that worked well in a controlled environment before deploying for testing in the intended use environment, the home.

7.2 Research Approach and Methodology

Since we aimed to understand usability issues and design preferences for dogs and humans (both trainers and owners), we needed to test with both types of end users (that is, both the human owners and trainers of MAADs as well as the MAADs themselves). To enable both dogs and humans to take part in and contribute to the research, we presented different configurations of our prototype to dogs and their trainers for use in a laboratory context. The study involved several iterative cycles of prototype modification and evaluation to incrementally improve the design.

7.2.1 Participant Selection

Participants for this study were based on dogs that could be available on-location at MDD for an extended period of time, so that the same dogs could participate through different iterations of the prototype as it evolved. Because of the length of time and availability required, we were able to select two Medical Detection Dogs trainers that were selected for the project based on schedule. The trainers then in turn selected the most appropriate dogs that they had access to and expected to continue to have access to for the duration of the study. The table below (7.1) shows the involvement of all canine participants across all studies (note that it disregards handlers). The highlighted column represents the study, where two dogs, Judd and Lady, participated (continuing on from the exploratory discussed in the previous chapter).

Dog	Exploratory Design Study	Lab Testing	Home Testing
Sullivan	X		
Marla	X		
Judd	X	X	
Lady	X	X	
Sebastian	X		X
Goliath			X
Evie			X
Jessa			X

Table 7.1. Matrix of all canine participants across all prototype studies. Participants for this study are highlighted.

7.2.3 Data Collection Methods

As in our previous studies, any time we observed dog behaviour with physical prototypes or during training sessions, we video-recorded the dogs and their trainers. Although this resulted in a large amount of data, we wanted to have the option to review the footage later with the dog trainers. Since we interviewed the dog trainer participants within the context of these task-based training sessions, we did not need to audio record, but rather usually let the video capture the verbal conversations as well.

7.2.4 Potential Limitations

Again, small participant numbers were a potential limitation of the work. However, our primary concern was to stabilize a prototype rather than perform large-scale testing. We hoped that even with two dog trainer/combinations, we would eliminate a lot of "gotchas". "Gotchas" are a computing term that originates from programming, where a gotcha is a valid construct in a system that works as documented, but is counter-intuitive. A gotcha can thus be a feature of a system or design that works as intended but causes unintended results. For example, one gotcha we discussed in this context, was the idea of creating a toy-like interface that the dog would find easy to engage with, but in turn would engage with when not intended or required. Another example of a gotcha is from Study 3 described in Chapter 6, where a quick-release magnet interface worked beautifully for its intended purpose, but resulted in the dog "sticking" to a nearby file cabinet.

By working closely with these two participant pairs, we aimed to improve usability over several iterations before home deployment, when we planned to move to a larger number of participants (see Chapter 8).

7.2.5 Ethical Considerations

Like the previous studies, human participants were given a consent form to sign (see Appendix B), and participating humans also signed the same consent form on behalf of any canine participants, which were in this circumstance given consent by their human guardians. Similar to the last study, with this work we intended to have dogs interact with novel interfaces that they would not routinely otherwise do outside of the research context. We still believed the study presented minimal risk to physical or psychological harm as canine participants were at all time under the direct care and supervision of their trainers.

7.2.6 Data Analysis

To analyse the data for this study, we followed almost entirely the same approach as the last study, described in §6.3. Again, the video footage of the dogs was not analysed for gesture or interaction under any framework; since this was exploratory work, we wanted to take a ground-up approach, and perform analysis on the discussion and interpretation of the dog's responses.

Interviews with the participant trainers that were recorded with audio were transcribed and thematically analysed, using the same hybrid approach as discussed in §5.2.6. Whereas before, mostly open coding was required as there was no previous work to take a codebook from, this study was more influenced by the pervious study's code (Study 3, Chapter 6) framework, which made for faster identification of themes and analysis.

The only notable difference between the qualitative analysis procedure for this study as compared to the previous study, was that less code-chunk subset selection and dynamic analysis occurred, as the data was collected in a less on-the-fly manner than in the previous study. For example, in Study 3, we might introduce a dog to a certain material of toy and see how they reacted. If they reacted neutrally, we may have pursed that thread (conversation) and "ask" the dog if he thought something similar was more interesting or intuitive. While we did similar work here with the configurable detachments, the basic design of the system was solidified, so there were less variables (less features to customise). That is, instead of trying different modes of interaction completely, we tried different variations of the same system. This meant that we were able to record data and analyse it later, rather stop and code sub-samples of our data in order to make further data collection decisions.

7.2.7 Procedure

The research process for this study involved different iterations of design modifications and testing. Sessions for both dogs and trainers were booked at the training centre in hour blocks. The hour blocks included time to talk about the testing options, test with the dogs, and also to debrief and interview the trainers on their opinions of the dogs' user experience as well as their own. After these sessions, the design would be reflected on and amended according to the feedback, and another session booked to test the alarm with amended features. Three of these design iterations occurred (with some smaller bug fixes in between the iteration cycles).

High-Fidelity Alarm Design

Our initial prototype was influenced from the findings of our previous study, specifically, the model discussed in §5.4.1 that models different levels of emergency and different use cases for an alarm system. It also used the bite-and-pull mechanism of trigger that was selected in the study described in Chapter 6. Here we describe the basic initial design of the high-fidelity prototype: The design of the initial functional prototype featured three main modules:

ELECTRICAL COMPONENTS An electronic component that encapsulated the system's hardware and ran the system's software.
TRIGGER The release mechanism that provided a detachment functionality when enough pressure is applied to the attachment component.
ATTACHMENT The actual piece of material that the dog is intended to bite and pull off from the trigger.

Technical Implementation

We based our technical implementation of the prototype on the need for flexibility. At a basic level, we required the device, once triggered, to make a phone call and send texts. However, we also required handling of input/output devices and wanted to insure we could add, remove, or amend any features and aspects of the prototype without changing its basic design. Thus, we selected a combination of a Raspberry Pi microcontroller and an Arduino control board. We selected these two devices for our implementation to allow for the aforementioned required flexibility. Both devices are widely used, stable, off-the shelf products that allowed for rapid implementation based on a large, stable code-base and user support. Additionally, they were low enough cost that we could create multiple units and thus be doing user testing in parallel rather than with one participant at a time. Rather than using either the Pi or Arduino, both of which have models that can be adapted for connectivity and support I/O, we used them in combination. This is because at the time of this work, the Pi provided especially easy off-the shelf ethernet connectivity, whereas the I/O was not as strongly supported. Conversely, the Arduino had excellent I/O support but limited connectivity options off-the shelf. By combining the two devices, we had an extremely flexible prototype that could run virtually any required scripts from the Pi controller, while the Arduino handled the I/O quickly and easily and could be modified without altering the Pi's code. This flexibility for switching different inputs and outputs was required because we wanted to be able to dynamically adapt to unforeseen user needs of the canine and human participants for a new system. In this regard, our selection of physical prototype implementation reflected our methodological approach, which was to leverage modularity and rapid prototyping to allow for a new form of participatory design with non-human users.

The first version of the prototype used Raspberry Pi Model A and with Arduino Uno. The second version then switched to using the newer Raspberry Pi B+ model and Arduino Leonardo board. The Arduino was used for input and output control and the Pi to control audio and internet connection. By using both components rather than just Pi, we were able to leverage the Arduino's superior I/O handling and the Pi's superior media handling and ability to run Python scripts to control the device logic. By using both a Raspberry Pi and Arduino for this prototype, we were accepting a trade-off of increased space and power requirement in return for ease of implementation and flexibility of components.

Figure 7.1: First functioning prototype mounted on a wall: note it is made up of three component boxes attached together by various wires. The phone is mounted on the wall for display purposes.

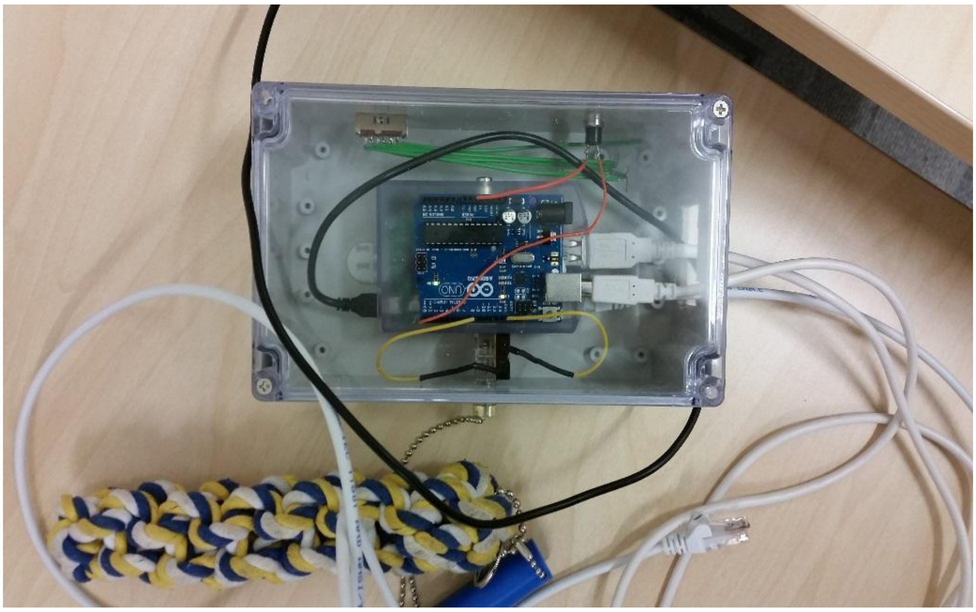

Figure 7.2 Second iteration prototype all in one compartment. The components were merged into one compartment to minimise installation complexity and to prevent extra cord connections that dogs could potentially get caught in.

Figure 7.3 The third version of the prototype used a new component box, added a logo, built in speaker, and light feedback to the units.

Figure 7.4 The final high-fidelity prototype. The main body of the prototype is a blue plastic components box with a dog logo. The built-in speaker has been removed but the Neopixel lights remain. The generalized switch adapted socket is shown on the bottom while Ethernet and power cords are from the side. One type of switch, a pull-switch, is shown for reference to show the male plug jack that fit into the unit's female jack.

Prototype Functionality and features

Here we provide an overview of the features of our system, comparing the different iterations of the prototype.

Feature	**Version 1**	**Version 2**	**Version 3**	**Version 4**
Type of switch	None- pull-and-detach only	None- pull-and-detach only	None- pull-and-detach only	Pull-and-detach, button, or any other switch with male jack
Cancellation button	Included	Included	Included	Included
Light feedback on trigger	None	None	Neopixel	Neopixel with colours/patterns and can turn off
Sound feedback on trigger	Text-to-speech audio, non-built in speaker	Text-to-speech audio, non-built in speaker	Text—to-speech audio, built in speaker	Text-to-speech audio or uploaded mp3, external speaker
Component encasing	Multiple	Single	Single	Single
Mounting height	Adjustable	Adjustable	Adjustable	Adjustable
Detachment resistance	Two settings	Two settings	Three settings	Three settings
Detachment type	Any	Any	Any	Any
Configuration interface	Local unit	Local unit	Web server	Web interface

Table 7.2. Matrix of prototype features by version.

Version 1: First functional prototype

The first prototype consisted of a pull-and-detach switch, based on our findings in the last two studies. It included a cancellation button, again, because this had shown to be a requirement to allow emergency contacts to not be called in an event of an accidental triggering of the system. The first version did not have any sort of light or visual feedback, but did provide audio feedback if an external speaker was plugged into the Raspberry Pi component. The components were in separate encasing (to allow for modularity at this early stage). The system could be mounted at any height necessary, which remained a feature throughout. Similarly, all versions had the ability to change the attachment type (tuggy) that the system used. Finally, the first version of the prototype had to be configured directly on the local unit by connecting to the Raspberry Pi directly on the same network via SSH.

Version 2

The second version of the prototype was identical to the first except all components merged into one component box. This change was made because we had settled on what physical components were going to be used moving forward, so having multiple component boxes became unnecessarily messy.

Version 3

The third version of the prototype made more significant changes. Importantly, it added light feedback based on our findings (see below). It also added a built-in instead of internal speaker and an additional resistance setting for the detachment of the tuggy. Finally, the configuration method was changed to a web server so that it could be configured from another network automatically.

Version 4: The final prototype

The fourth and final version of the prototype was altered to take a generalised switch (see findings in next Chapter). The patterns and colours used for the light feedback were improved, and a configuration option to turn off lights completely was also added. The built-in speaker was removed and reverted to external speaker. Finally, the web server configuration interface was given a web interface accessible by browser, so that the units could be updated real-time from any smart phone or computer.

7.2.8 Training process

We structured the study to both train the dog to use the prototype and test the prototype at the same time. 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. So, initial sessions focused simply on having the dog bite and pull the tuggy from the prototype, while later sessions involved mock-emergency situations where the trainer collapsed on the floor and the dog then was expected to trigger the prototype with no further guidance or cue, other than this collapse.

Both dogs in this study already knew how to 'tug', and also how to retrieve an object on command. Thus, the primary 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 behavioural cue. Behavioural cues can vary depending on the context of expected emergencies. For example, the trainer may simulate fainting and collapsing on the ground as a behavioural cue, or they shake as one would during a seizure. Acting out these emergency-like behaviours during non-emergencies teaches the dog to recognise these actions as training cues rather than a reason to be distressed. Then the verbal command was then 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 subtler cues are intended to correspond with a "level 3" emergency as described in §5.4.1; that is, there is no obvious or sudden behaviour that the handler will demonstrate to indicate to the dog that it should interact with the alarm system.

7.2.9 Testing process

For each assistance dog participant-trainer partnership, we held testing and feedback sessions whereby the dog was encouraged to engage with the prototype. The dog and trainer partnerships were presented with different iterations of the prototype across the span of several months.

Installation

The mounting location of the prototype was determined in each session by a combination of logistics (where wall-space in the office environment was available), but also by the intent of the session, i.e., context-based. For example, if we wanted to see how the dog would interact with the prototype when it was positioned in a high-traffic or high distraction area, we would mount it in a main office room. Alternatively, for dogs just learning how to use the prototype in early sessions, the prototype would be mounted in as quiet and out-of-the-way location as possible.

Evaluation: Observations and Semi-Structured Interviews

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 with it. 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 alterations might need to be made.

7.3 Findings and Discussion

Testing with the two partnerships provided us valuable feedback on our system and the training process to use the system, which we will review here by feature of the design.

Figure 7.5(L).The trainer participant, Sabrina, has pretended to collapse suddenly very close in proximity to the mounted prototype. Here Judd is shown mid-pull as he uses the bite-and-pull interface while Sabrina continues to not move or direct him in any way. **Figure 7.5** (R) The trainer participant, Linda, has collapsed on the ground. The prototype is mounted in the distance. Here, Lady is shown having already retrieved the tuggy detachment and is bring it back to Linda as she has been trained to do.

7.3.1 Detachment Resistance of Tuggy

We define *detachment resistance* to be the amount of force required to detach the tuggy from the release trigger of the prototype. Our initial hypothesis was that a lower detachment resistance would result in more of a challenge for the pull-task, which could in turn make the act of biting and pulling more enjoyable for the dog. This seemed to be corroborated by testing with Lady and Judd. For both canine participants, we observed a correlation between detachment resistance and playful behaviour exhibited by the dog. Lady especially displayed playful behaviour when initially interacting with the tuggy. As training progressed, Lady became overall less playful with the object, possibly because some of the novelty of the play interaction wore off as training continued.

Both dogs seemed to be more playful and enthusiastic when they used the device set to a higher detachment resistance. The trainers commented that for many dogs they work with they would assume a similar behaviour, as most of the dogs in their training program exhibit a strong desire to play tug-of-war and enjoy pulling games in general.

We were not sure if the highest setting of detachment resistance would discourage either dog, however this was not an issue. Sabrina Said of Judd: "*He'll pull as hard as he needs to pull on that. Nothing will be too strong! He knows he's meant to pull it off and he'll pull harder and harder until something happens*". When we asked the participating trainers if having the adjustable detachment resistance was a helpful feature, both trainers answered that yes, it would was helpful to have three or four "pressure setting choices". One trainer could envision setting the resistance lower for some of the less confident or boisterous dogs. Another could envision increasing the detachment resistance as training progressed so that the dog continued to be engaged.

7.3.2 Mounted Height of Device

We adjusted 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, Judd 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. While Lady and Judd were similar heights and seemed to find a similar mounted height optimal, other dog users will be shorter or taller. 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.

7.3.3 Different Types of tuggy detachments

Both trainers felt it was important to be able to interchange different type of tuggies independent of the rest of the interface. We observed both in this phase and in our previous exploratory phase that different dogs responded more or less positively to different types of detachable tuggies. For example, Judd 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.

7.3.4 Use Environment

We also found that for a dog to successfully trigger the alarm, the dog may need to overcome environmental distractions and challenges. For example, in one training session, when Sabrina collapsed with other dogs (that were not trained to use the alarm) in the room, they interfered with Judd 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, Judd 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 Sabrina. Judd 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 characterising 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.

7.3.5 Compactness

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, both dogs at one point got caught in the cords, which of course 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).

7.3.6 On-board speaker/audio feedback

During this study, it became apparent, based on user feedback, 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 behaviour 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 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 forgetting turning the speaker on and off with each use.

7.3.7 Light pattern and colour coding

Both trainers expressed uncertainty as to what state the device was in with the initial two versions of the high-fidelity 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. A 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 already 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.

7.3.8 Canine and Human requirements

This study has identified a need to recognise both canine and human users' requirements, so as to understand what trade-offs 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, if they were required to be. 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 prioritised, 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, neighbours, and emergency services could potentially be contacted by mistake in a false alarm, causing unnecessary worry or resources to be used. 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 accidental. 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 colours 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 experiences were not effected by this element of the system. This can imply that for a canine-human partnership, during the design process, requirements can be flagged as canine or human, where there is either overlap (thus trade-offs are required), or where they are divergent.

7.5 Chapter Summary

In this study phase, we have started with a low-fidelity prototype from the last study and improved it to a high-fidelity functional prototype. The final version of the prototype had many features changed, removed or improved and resulted in a stable and usable interface for both dogs and humans. By testing our prototype within a training framework, we were able to leverage existing training practices as discussed in Chapter 4 and also to simulate real-life emergencies so that we could stage real use cases. As a result of this study, we emerged with a final prototype design that was ready for home testing with real MAAD partnerships.

8

Home Evaluation

Based on the findings of previous studies, a fifth and final study took a fully implemented, functional prototype and conducted home testing with canine and human end-users.

8.1 Motivation

In the wild studies are important in demonstrating how new systems, devices and services are adopted and how they affect users' daily lives, beyond issues of mere usability (Rogers, 2012). Testing in a lab environment, while often helpful or essential, can still provide an unrealistic setting that can miss certain elements of the design's success or issues. Given that humans and canines co-habit and share spaces, and close interpersonal relationships, we wanted to investigate what effect using such a system in actual home environments would uncover. Until this study, all of our testing with canine participants had occurred in their training environment (at Medical Detection Dogs' training centre). We had established that dog users could effectively use the device in this semi-controlled environment, and now wanted to see if the system remained effective when real-world variables were introduced.

8.2 Research Approach and Methodology

For this study phase, our research approach took on a new focus. We wanted to evaluate the high-fidelity prototype developed throughout all the other phases in a real-world environment; thus we needed to conduct in-the-wild evaluation, in order to be able to collect data that could offer a level of unpredictability. As such, our approach was to use in-situ methods of deployment and evaluation into a home environment.

8.2.1 Participant Selection

As mentioned above, the participants were all selected from existing participants from other studies in this on-going research project. All partnerships were asked at the end of the in-depth interview phase (see Chapter 5) if they would like to be contacted to continue further participation in the study. When a prototype became ready, we contacted the participants via email and asked them if they would be interested in doing home evaluation with us. Table 8.1 shows the participants the matrix of other study involvement.

Partnership	Exploratory Design Study	In-Depth Interviews	Home Testing
Caren & Sebastian	X	X	X
Catherine & Merlin		X	
Yvette & Nemo		X	
Tim & Goliath		X	X
Karen & Evie		X	X
Ray & Jessa		X	X

Table 8.1: Matrix of participant partnerships across different phases of prototype testing.

8.2.3 Data Collection Methods and Procedure

After confirming participant participation for home deployment, we setup initial home testing visits with our four participant partnerships. At these initial visits, we conducted brief interviews to catch up with participants about any new health developments or training developments for their particular situation. We then discussed where in the home would be an ideal location to mount the alarm, and did basic initial testing with the dogs to determine particular configurations for the alarm. The location of the prototype was determined by each individual participant's home environment and layout. Depending on the partnership, during this session the alarm was tested in different scenarios.

During visits, the interviews with human participants were recorded using audio-recording equipment; video footage of any "interviews" with the dogs (i.e., a dog testing a prototype or present with their owners for any research activities) was also recorded. From previous studies, we had learned that video footage of canine participants was essential in being able to evaluate dog's user experiences and preferences. In addition to video footage, real-time notes and observations were sometimes taken when a dog was testing the prototype, so as to have a guideline for later analysis. However, preference was given to video-recording the dog's testing sessions rather than taking the time to make notes, since all footage would then be reviewed later, priority was on directing the sessions and interviews.

Prior to participation, we stressed to each participant that the alarm systems were being tested, not fully deployed. That is to say, we wanted them to know that our work was to learn more about and improve this novel interface and system, rather than install a robust, market quality system they could rely on to save them in an emergency. For this reason, any alarm units were not left fully functional when installed, but rather fully functional during testing sessions and partially functional when researchers were not present in the home.

8.2.4 Potential Limitations

Potential limitations of this study were, again, a relatively small number of participants. However, for an in-the-wild study, where numbers are often small, we had adequate participants that reflected different medical conditions and home environments. We focused on richness of data rather than large numbers.

8.2.5 Ethical Considerations

Like the previous studies, human participants were given a consent form to sign (see Appendix B). Also again, the human participated also signed the same consent form on behalf of any canine participants, which were in this circumstances given consent by their human guardians. Unlike the previous studies, this research involved changing the participant's environment by installing a device that they then were expected to potentially use and have their dogs interact with. As such, additional care was taken to ensure suitability for the research and that the installation of such a device would not disrupt or jeopardise the dog's existing training. Additionally, it was stressed to participants that the device was in prototype stage and was not intended in any circumstance to be relied upon, but rather, that they were helping us to test an as-yet-in development piece of technology rather than a finished product.

8.2.6 Data Analysis

To analyse the data from this study, we again, as for all four previous studies, did thematic analysis with inductive coding. However, whereas the first study used purely open coding, this study was able to draw upon the coding schemes of the earlier studies to identify themes (Table 8.2). In addition, new themes emerged as a result of the canine alarm technological intervention, discussed in our findings below.

We were able to take some in-home video of our participants dogs testing the unit while we observed. We did not get any video of spontaneous use because we did not install recording devices in the home as part of the deployment. To analyse the video we did get of the dogs using the system in their own environment, we showed a subset of footage (as flaged by event timestamps from notes). We showed them this footage during sessions at Medical Detection Dogs. Dog trainers and researchers co-located to watch the footage, and then the notes and transcripts from these sections were then used as data. In this way, we were able to continue with the same video analysis approach we had in all of this work, which ended up adapting a model whereby dogs would have real-time 'conversations' but also be retroactively "translated" by multiple dog trainers that were interpreting their behaviour and reporting on it to us. Our data set then became these interpretations. As discussed in previous chapters, the dog trainer participants were experts in their field, and indeed had trained many of the participant dogs themselves. In addition, it was standard practice at this particular training organisation to validate one's interpretation of canine behaviour with others if there was any doubt of how the behaviour should be interpreted. Future work would likely do well to take this a step further and triangulate the dog trainers interpterion with existing canine body posture models and biometric data.

Codes from previous study	Examples from Study 5
Medical-Emergency-Alert-Miss	"…[Well, he didn't exactly nudge me, I don't think. Sometimes it is hard to tell, I will say. But then next minute I was feeling low, **he knew didn't he**….I wish I could always tell for sure."
sMedical-Emergency- PassedOut	It's been a week or two since there was anything [bad] happening…But **I gone** the other night, on the couch. Only for 20 minutes. [Friend] was here, but he said [dog name] was giving the box real interest.
Medical-Emergency-Alone	"**I was home alone** the other evening […] I was just trying to get something I dropped on the floor, then I stayed sitting there for a moment and [dog] wasn't having it, let me tell you. He walked over by [the alarm] and I lay still to see what he would do. And of course he pulled it…"

Table 8.2. Example coding scheme from earlier studies as applied to Study 5's data.

8.3 Findings

Here we discuss the findings of the home evaluation with the human and dog partnerships.

8.3.1 Tim and Goliath

As first discussed in Chapter 5, Tim is a gentleman in his 50s that has Type 1 Diabetes and is confined to a wheelchair (see §5.3.4 for the partnership background from Study 2). They are motivated to participate in this study as they know many friends and members of the community that they think would benefit from such technology. Since they had previously participated in the in-depth interview sessions, during the first visit they are already familiar with the research work. In conversations with them they are both very focused on the issue at hand – the dog, the training and the user of the alarm.

Our first home session I arrived and installed the alarm with extra-strength wall Velcro strips. The alarm was placed on the *door* in the reception/lounge of the home. This location was picked not because it was optimal for the dog to access in any way, (or indeed convenient for the humans of the household either) but rather because of ease of access to the internet. Tim shows me the rooms of the house and explains that Goliath has access to all rooms at all times, however we still used the reception room/office since this is where the ethernet is located and the main room of the house. The way their house was currently set-up, there was nowhere else that had space that could easily reach the ethernet cord and power. We discussed that it would be preferable if the unit was wifi; barring that ethernet and power cable extenders would be needed, and cables potentially mounted to wall or floor to reach another room.

We first set the height of the alarm at 3ft. This was Goliath's first exposure to the system but he learned out to use it very quickly indeed. Tim showed Goliath the alarm (see figure 8.1). He then pointed at the alarm and told Goliath to "pull" with a verbal command. Goliath easily pulled off the detachment and brought it to Tim- simply as that! Seeing that the understanding and use of the alarm came naturally to Goliath, we then began testing different tuggies- a corded monkey fist ball, a rubber dog toy handle, and a soft braided fleece tuggy. For each different tuggy, it seems clear to all observing that Goliath still realised what he is supposed to do and how to interact with the alarm. There was no hesitation as he attempted to grip each different tuggy for the first time. However, with some tuggies, he struggled to physically execute his task. For example, the two rubber tuggies proved especially difficult for him to take hold of in his mouth. He did keep attempting to grab them, but kept not being able to get the right angle to grip the rubber tuggy with his mouth.

We spoke to Tim about the apparent ease of which Goliath was able to use the alarm. Goliath was able to use the command to fetch tuggies immediately, probably due to his extensive prior training as a mobility alert dog. Tim explained to us that Goliath is already accustomed to frequently picking up objects, pulling objects, retrieving objects, etc, since Tim is in a wheelchair and often has Goliath pick things up for him. Thus, Goliath may already have a world view such that he sees everything as an object that can be manipulated on command.

During our interview, Tim and Jeff brought up that they had previously trained their last assistance dog, the one they had before Goliath, to use buttons for emergencies using peanut butter lids. Once their previous dog had learned to target and put his paw on the peanut butter lids, they switched it to a similar size, shaped and colour red button. While having their past dog trained to use a button in an emergency was extremely helpful at the time, currently, Tim does not use such a button alarm system with Goliath. He explained this is not because the system was not helpful, but rather because he is now retired and his partner is retired, so he does not end up alone at the home experiencing emergencies anymore. Tim and Jeff emphasised that having the device in their home and training Goliath is fun- they said "*it's great seeing him, isn't it, just knows what to do. He's special, isn't he?"*. Unlike other participants in this work, Tim and Jeff have raised and trained this dog almost completely themselves, so the pride is obvious.

Importantly, Tim and Jeff emphasise to us that this alarm would have been extremely helpful to them in the past before Jeff was retired, and that they presently many friends with medical conditions and assistance dogs that this alarm would be a major help to.

Figure 8.1: Tim draws his dog, Goliath's, attention to the alarm by gesturing towards it as an initial introduction. Goliath seems curious about this new device in his home.

Figure 8.2: In these photos, Goliath has been instructed to activate the alarm. He rears up to get leverage on the flat rubber tuggy attachment. Note the alarm is attached to a door; this is because it is temporary testing session, not a long-term installation.

Figure 8.3: Goliath again activates the alarm when commanded, this time pulling on a “monkey fist” tuggy attachment (a braided rope with a rope ball at the end).

Figure 8.4: Goliath demonstrates three different ways of activating the alarm; Rearing up without touching the door with his paws, rearing up using the door for support, or reaching up without rearing to pull the tuggy.

8.3.2 Karen and Evie

Our next partnership, Karen and Evie, are a partnership living alone with no other people in the household other than a pet dog, Woody. When we arrive for the first home evaluation visit, I interview her about more specifics of her situation (see Chapter 5.3.5 for the participant partnership’s background).

We discuss whom the alarm should call and text, and Karen says it should go through to Ron, her 70-year-old neighbour who she walks her dogs with regularly. She notes that Ron’s wife died of

Diabetes. She describes the strong sense of community in her cul-de-sac. *“In my street, there is nobody that I don’t know. Everybody knows everybody. It’s amazing. At Christmas, if there’s snow, we all clear the road together. Everybody is absolutely fantastic.”* Community is important to Karen: she stresses that she always shops locally, and supports all her local shops, including her local pet shop.

After interviewing Karen, we do an initial training session to formally introduce Evie to the alarm. She has done pervious work with her dog trainer, Harriet, learning to pull objects in preparation. We discuss which attachment would work best for Evie. Harriet advises that Evie might respond well to a ball on a rope attachment. Another trainer was doubtful; saying *'isn't that too enticing*?' Evie’s trainer clarified she didn't mean an actual ball on a rope, but rather a knotted part of the rope like a 'monkey fist' just for grip not to entice, explaining: *"so she likes carrying it, and holding it, but I don't think it would be self-rewarding like a tennis ball".*

At this point, Evie is being taught to use the alarm by a verbal cue “pull pull”, rather than chaining this cue to a fall or seizure. This is to make sure she understands *how* to interact with the alarm, not *when*. She will be taught when once she is confident on the expectation of her interaction with the alarm (pull off the tuggy and bring it to Karen). It takes Evie about three times to immediately go to the alarm and pull off the monkey-fisted tuggy without hesitation. In a later session, we turn on the alarm’s sound so that Evie can get used to the robotic voice noise that it makes. Evie, like other dogs in the study so far, shows almost no outward reaction to the alarm making a sound, but the trainers interpret this not as the dog not noticing the sound, but rather that they are “not fussed”.

On our next visit, it is time to install the alarm and leave it mounted in Karen’s home. It is decided between Evie’s trainer and Karen to mount the alarm in Karen’s bedroom, as opposed to downstairs or in an upstairs hallway or other room. This is to allow Evie easiest access to the alarm, since that is where Karen is expected to be when any incidents occur. We install the alarm in Karen's bedroom, directly next to her bed. I explain to Karen that the colour coding and light feedback system and provided her with a hand-drawn diagram/chart. We show to have Karen best mount the system and decide to use extra-strong Velcro for now as that is what she's been training at on the centre without issue.

Evie seems to recognize the alarm from previous sessions and when given the command to pull. She wags her tail and seems engaged in the training session, although she is more focused on Karen now than she was in previous sessions. When the trainer gives the command for 'pull-pull', she seems like she is dividing her attention between the task as she walks over to the alarm, and looking back at Karen. However, she successfully retrieves the tuggy each time asked, as well as when Karen slumps to the floor. After this session, we leave Karen and Evie with the alarm "deactivated" such that it could not make calls, but was otherwise fully functional. Harriet gives Karen specific instructions on how to continue Evie's training on the tuggy and staging mild, 'pretend' seizures to link the verbal cue to "pull pull" with a physical cue.

During a final session, we debrief with Karen about how alarm has been in her bedroom and if Evie has used it during any events. Karen says having the alarm makes her feel safer and that it is also viewed as "extremely cool" by her friends and neighbours. Karen describes that Evie has forcefully, more than once, pulled the alarm off the wall, which is a result of improper mounting. Karen and Evie's trainer, Harriet is sent up to resolve this issue in a trip and also to work with Evie's general alert training. Evie was getting very exuberant with her pulling off the alarm, which she didn't exhibit earlier in training. This might be because she is worked up in the real-life situation of being concerned and knowing there is a real problem.

Still, Harriet and Karen are very encouraged by the fact that Evie goes to pull the attachment off the of the alarm both when Karen asks her to “pull pull”, but, importantly, also when Karen isn’t feeling well and Evie seems worried. Harriet and Karen interpret this as Evie realizing that the alarm has special value and is something she can trigger to get attention or somehow accomplish something in a stressful situation. It is not clear the extent at which Evie understands the context in which she should use the alarm: unfortunately, the duration of the study runs out before this can be further explored. Harriet says she would be very happy indeed to have a fully-functioning, reliable market version of the prototype in the future if possible.

8.3.3 Caren and Sebastian

Our third home evaluation partnership is Caren and Sebastian. Caren is in her 50s and has Type 1 Diabetes (see §5.3.1 for the partnership’s background from Study 2).

We visited Caren’s home, a small flat within a building that is all assisted living flats with a manager on-site. We determined the alarm should be installed in the bedroom. Caren said that she is most likely to have a serious incident in bed, and since the doors are always left open in the flat, if she were to have an incident in the sitting room, Sebastian could still access the bedroom as it is only approximately 4 yards away. We used Velcro to test the height of the alarm until we found an estimated good height, then asked Sebastian to interact with the alarm.

Sebastian had previously been taught to pull a wall-mounted tuggy on command or when his owner falls over in the previous exploratory phase of this work (see Chapter 6). Thus, once the alarm was installed, we asked Sebastian to test it (with the command ‘pull-pull’), and Sebastian remembered his training and immediately when over to the alarm, pulled off the tuggy, and took it to Caren and dropped it in her lap. This excited everyone, that with no reminding, months after his initial training for the system, Sebastian was able to remember that he was supposed to go pull off the attachment and bring it straight to Caren. We repeated this testing from a distance and on different occasions to confirm that Sebastian understands how to interact with the alarm.

Sebastian continued to be tested on the alarm in mock training sessions. Fortunately, since the installation of the alarm, Caren has not had any serious incidents. Twice, Sebastian has pulled the alarm when Caren was not noticing his alert and had low blood sugar levels, though she was not unconscious. This use implies that Sebastian knows that the alarm will get Caren's attention. Due to Sebastian's inclination to do this, the originally window of 40 seconds to cancel the alarm was extended for this partnership. Since the alarm has a cancel button and is configured for a 1.5 minute delay before actually making calls, this behaviour has not been considered a negative as if she is not in an emergency she can easily cancel the alarm. Caren has expressed her excitement in being able to contribute to the development of the technology. She is very disappointed that the study has to end and she cannot be left with a working, long term version of this system to have in her home.

8.3.4 Ray and Jessa

Our last home evaluation pair is Ray and Jessa. Ray is in his 20s and currently living alone with medical assistance dog, Jessa. On our first home visit, as with other participants, we interview Ray further about his specific medical condition.

Importantly, since Jessa is only awarded if Ray wakes up, Jessa is currently not being rewarded many of the times she is doing the correct behaviour (pressing the button). This is resulting in her becoming less and less interested in the button over time, as she is not being re-affirmed that she is doing the correct thing by hitting the button when he does not wake up. To solve this issue, the system either needs to successfully wake up Ray in more cases, or automatically reward Jessa (with an auto-dispense treat releaser).

In this situation, we decide that rather than introduce Jessa to a new system with a new mode of interaction, she should remain using a button as she does now to wake up Ray. However, for a button to be compatible for our system, which is designed with a pull-cord switch, we have to alter it. We altered one of our units to take a female switch jack so that any switch-adapted device can activate the alarm. We then purchase an off-the shelf button called Big Mac to use as a more robust button. BigMac is developed for special needs children and adults; this it is designed to be robust and withstand a large amount of pressure when the user hits it.

In order to install the alarm, we had to request Ray's family run an Ethernet wire from another room to enable internet access for the device. This was a non-trivial job as they could not have exposed wires, so the cable was drilled through the ceiling and into Ray's bedroom ahead of the installation visit. We adapted an existing alarm that is pull-tuggy activated to instead take a 3.5mm switch input. Then, we setup the alarm in Ray's bedroom by connecting the existing button into our alarm, which was secured on a shelf close to the button. After confirming the alarm was working from the button activation, we did no further training, since Jessa was already accustomed to using a button when she heard Ray's monitor go off.

During the initial period that the alarm was installed, Ray continued to have some instances of not waking up even when the button (and thus speaker) was activated. However, Ray's parents were now able to hear specific pre-recorded sounds when Jessa triggered the alarm and the button was robust and stayed mounted by Ray's bed. Since Jessa only gets a reward for hitting the button if Ray or his parents wakes up, this has significantly improved Jessa's training. Before, if Ray did not wake up, she was not rewarded (reinforced) for pressing the button. Now, within a short time, Ray's mother is able to wake Ray up herself and prompt him to treat Jessa, so that her training is supported and she does not become disinterested in the button because of lack of reinforcement.

This highlighted an interesting issue regarding different modes of interaction to trigger a system like ours. In Chapter 6, the button interface was excluded because it as not considered the best ergonomic choice for the dog, and because it had a lack of discrete feedback to indicate to the dog that it had successfully completed its task. However, this dog, Jessa, was already trained to use buttons. In order not to disrupt his training, we adapted the alarm to be able to use a button instead of the pull-and-detach. Because the system had been designed to be modular and flexible (and required only an activated switch to trigger the rest of the systems functionality), we were able to accommodate the dogs previous training. We note that in future designs, there may be a tension between the optimised ergonomic design and changing the dog's training.

8.4 Discussion

After evaluating the alarm for a test period in our participant's home, we saw emergent themes regarding the design and purpose of the system. Here we discuss some of these themes and the implications for future work in the area of canine emergency communication interfaces.

8.4.1 Effect of having alarm in home

All of our participants reported that the process of installing the alarm and doing testing sessions with their dog was overall positive. Several participants stressed that it felt good to be working towards a goal and that it was "comforting" or "encouraging" that research was being done to help individuals such as themselves. This feeling of support and attention to their particular circumstances permeated the interviews and sessions we had with the participants. On the other hand, installing the device in their home also required extra dedication and energy towards the training process with their dogs, which some participants had not spent considerable time on for years since the dog had initially been placed with them.

Participants also mostly agreed that having the alarm in the home was a positive “talking point” with friends and family. One participant, Ray with his dog Jessa, was an exception to this. Ray feels it is better to remain private about his medical condition. He is usually able to do this since most of his issues happen overnight in the home. So, Ray’s alarm was installed in his own bedroom for testing and thus not noticeable to visitors in the home.

8.4.2 Continued need for configurable features and client control

From our initial home testing visits and throughout the deployment process, it became very apparent that there was additional need for configuration within the interface. From our design phase, we had already discovered many user needs and added design features accordingly. We created an alarm that allowed for different types attachments for different dogs, that could be mounted at different heights, and that could play different sounds and customised recordings all based on the users unique needs.

However, this phase exposed a further need for flexible configurations. For example, with Ray and Jessa, we needed the alarm to be triggered by a button in addition to a pull-release trigger, so needed to adapt the system accordingly, so that they could use it for their particular circumstance. For Karen and Evie, with the device being upstairs in a two-story home, we found that we had a need for the device to create a louder sound. This was because the sound in this case needed to act as not only a feedback for the client, but also carry into other rooms across the house so that Evie could not accidently contact people in a non-emergency. To account for this, we adapted the device so that any external speaker or amplifier that used a 3.5mm jack cord could be plugged into our system. In this way, the alarm could be used with a user’s home sound system if desired or necessary. Yet another configuration that proved to be required in home deployments was control over the units lights. Our lab testing and initial home user testing had not uncovered an issue with the devices light. However, after a period of deployment, some users expressed a desire to be able to control the lights on the unit for various reasons. This was most important in the case of Ray, who had the unit installed in his room. At night-time, the lights on the device proved extremely bright such that they lit up the entire bedroom. In response to this, we added a "night mode" feature to the alarm, where the user can toggle light feedback on and off via the website control panel.

8.5 Chapter Summary

In this chapter we have reviewed the work for the fifth and final study of this research project. We have reviewed additional design considerations and themes that have emerged from in-the-wild evaluation of our canine emergency communication system. In the next chapter,9, we will look at the big picture of where this work sits and discuss the practical and methodological contributions that have emerged from the research as a whole.

9

Discussion: Animal Computer Interaction and Emergency Canine Systems

This chapter reflects upon the overall work of this thesis and where it sits within the evolving landscape of Animal-Computer Interaction and canine interaction design. We discuss the methodological and design contributions of this work, focusing on how dogs can be involved directly in the design process, as well as specific design requirements for canine emergency remote communication systems.

9.1 ACI and canine-computer interaction landscape

In the time since this thesis work was embarked upon, research in Animal Computer Interaction has become increasingly common at computing venues. That is, more in depth research involving the development of technology for animals is situated as a design task, within a design framework. More species user groups are being worked with and designed for. The area of canine-computer interaction and devices created for dogs seems especially prominent. Technology is only becoming an increasing presence in the lives of modern domesticated animals. For example, while there were real-time GPS and smart collar tracking devices available in December 2012, options were somewhat limited, and pet technology for assistance animals still more niche. By December 2016, wearable, lightweight computing has benefited this product area, and there are numerous pet monitoring systems and wearable pet tracking devices for consumers to choose from (Appendix

C). If pet-tech is continuing to enjoy mainstream success, ACI is continuing to have more of a presence in the CHI community. Publications from this thesis have directly contributed to the ACI and canine community, and many other works have been published in recent years about developing specialised technology for canines to use in emergencies and to communicate with human "co-workers".

Our work provides one example of a case where including canines in the design process was successful. That is, a design was iterated upon and successfully deployed to end user home environments, as part of a training framework and integrated into the home, successfully activated in situational context (in mock emergencies). While one could argue something similar could have been achieved with an off-the shelf product (such as pull alarm intended for human use), the fact is that from a methodological standpoint, this work has demonstrated some of the challenges and successes of working with another species, and, when combined with all the other work being done in this area, the landscape of how we can successfully work with non-human technology users is taking shape.

9.1.1 Animal Computer-Interaction: From Designing *For* to Designing *With*

User-centred design is essential in creating usable, effective interfaces that move beyond just meeting the physiological or cognitive abilities of a user group. HCI has long moved from the assumption that, in order to understand the subtleties and individualities of real users, designers must seek active participation of the users themselves in the design process (Muller and Kuhn, 1993). For any technology to be developed to achieve specific goals for specific users, requirements must be elicited from those who stand directly to gain from its development. The Participatory Design movement has seen an increasing focus on users taking an active role in technological development (Muller, 2003), directly entering into the conversation of the design process. But with ACI, there are obvious obstacles, first of all because the language of such conversations is not shared across species.

ACI faces an ongoing challenge when looking for ways to design *with* rather than *for* the users of ACI technologies. While designing *for* animal users involves taking into consideration their capabilities (sensory, physical and cognitive), it does not necessarily involve them directly in the design process. For example, a design may account for the fact that an interface needs to be located at a certain height, or afford a certain modality of interaction to allow the animal to access it, but may not account for the specific habits or preferences of individual users in real-life use contexts. In order not to miss these individual requirements, the user needs to be involved. Ways to involve the non-human user are still being actively researched within ACI as more researchers address the challenge and this work directly contributes to this effort.

9.1.2 A Species-Informed Approach to Participatory Design

In HCI there are many established methods that can be used to gather user requirements for and evaluate technology from the user's point of view. However, determining what an animal user prefers when it comes to the interaction with a system is far more challenging (Ritvo and Allison, 2014), given the obvious communication barriers that exist between human designers and non-human users. Indeed, answering the question of what an animal wants in *any* context is a complex issue, which over time has been addressed in different ways by experts of animal behaviour and cognition. As a result, in the field of animal studies, there exists an established body of research that can be drawn from to address the methodological challenges encountered in ACI design practice (see §2.3).

The approach taken by this work has been to start by designing for established evolutionary characteristics, such as those outlined in §2.4. Starting from the animal's biological characteristics clearly provides a basis for designing for particular species. Designs and prototypes developed on this basis can thus be proposed to individuals and used to engage them in the design process. To do so, we have leveraged methods derived from HCI or related fields, to understand the design context, and learn about animals' requirements, through ethnographic observation, and gather animals' responses to such designs, with rapid prototyping. This includes surmising any existing specific practices that may further inform the design (for example, in the case of this work, the practice of assistance dogs using bringsels and blood test kits as a way of communication). Practice becomes very important when involving animals in the design process, because it is mostly through practice and physical engagement that they express themselves and their preferences, and learn, as we have seen; hence our modular approach to rapid physical prototyping to maximise permutations and offer the dogs choice. Within ACI research, where the animal has almost total control over their interaction with a system and can choose whether and how to engage with it, what they do in practice is key in understanding what they need and want in a design. This is especially important when designing systems that the animal needs to be able to use *autonomously*, that is, by directing their own interaction with the system, as is the case with assistance dogs in emergencies. Autonomous use needs to be supported by perfect usability, because if a canine user is unable to engage with a system successfully when they are motivated to do so, the impact on their learning and performance can be highly significant. In the next section, we further discuss the importance of an assistance dog user being able to engage with a system with varying levels of autonomy.

The Question of Autonomy

Although dogs are indeed trained for a specific range of behavioural actions and responses, they still have some degree of decision making ability. For example, many dogs are trained to sit if a handler gives them the verbal command 'sit' and makes a certain gesture. The dog's previous experience based on operant conditioning likely tells them that if they sit, they will be praised and rewarded, and if they do not, they will not be praised or rewarded, but may even be admonished.

However, this does not mean that the dog will automatically sit. In this example, the dog still has the ability to choose whether the motivation to a certain outcome is worth it, and this will vary (like human users) on a variety of factors. Here, there is a blurred line between training in terms of a conditioned response that we expect a dog to always follow specific training (i.e, hear a noise, press a button) and between the idea that training is what teaches a dog how to use a particular interface (where if a dog then has a mental map of what the interface does and how to use it, they can then make their own decision).

9.1.3 Types of emergencies that assistance dogs face and why it matters

In Chapter 5, our findings included a model of a spectrum of emergencies with different levels of emergency that an assistance dog can face when alone with their owner. 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 arises. We have also seen 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). The more incapacitated the human, the less directed or clear cues the dog has to engage with the system, and the higher the burden of driving the interaction is on the dog.

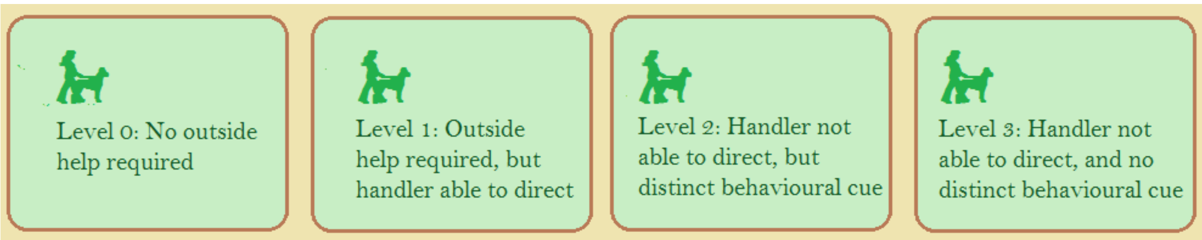

Figure 9.1 The levels of emergencies derived from Study 2, repeated here for convenience

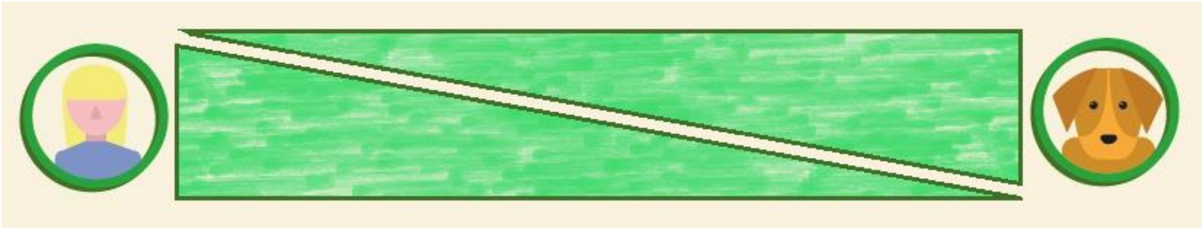

Figure 9.2. The degree to which human handler or the assistance dog is driving an interaction with a device during an emergency is illustrated above. On the left-hand side, we see one extreme, where the interaction is controlled by the human handler, even though the dog is the one physically interacting with an interface. Here, the handler is totally cognitively aware and directing the dog with either gestural or verbal cues, or both. On the other extreme of the spectrum, the handler is unconscious and has not provided any warning or distinct behaviour before falling unconscious. Here, the onus is completely on the dog to know that it is appropriate to trigger a device, and how to do so.

The work presented in chapters 7 and 8 implied that for a system to be used with no human guidance, by assistance dogs, a large influence on the success of the design will be contextual. Thus, much of the success is related to the training or learning that the assistance dog undergoes in relation to the system rather than the system itself. Of course, the system must still be possible, and ideally easy, for the dog to use. However, we found that even the most straightforward of interfaces for a dog to use, that required either no or little training (less than 5 minutes) to get the dog to activate the system physically, could still require many hours of long-term training to be successful when the system is used in a real-life situation. As autonomy, and the stress caused by the emergency situation increase, the likelihood of the dog to easily draw on their training and learning of the interface decreases. This is easy to envision in other interfaces as well. For example, most mobility assistance dogs can activate a button if it is within their physical capabilities, when instructed by their handler. But the difference between activating this button by command (with support from handler) versus activating particular buttons in particular situations, semi or wholly autonomously, is a significant one. Since much of the potential failure of a dog to activate an emergency system depends on the dogs understanding when to use the system, not simply how, it is all the more important that the system be ergonomically optimised to used, and remembered how to be used, by the dog. A complex system may be possible for a dog to engage with advanced real-time support by their handler. But with little to no handler support, a user-friendly system becomes imperative.

9.1.4 Tension between the need for proximity and non-worn interfaces

It is well-established that dogs are highly aware and responsive to human body language (Hare and Tomasello, 2005). Indeed, dogs have been shown to choose to trust human body language over their own observation of a situation (Kaminsk and Tomasello, 2006). Many assistance dogs are even more tuned into their handlers' body language than pet dogs; this awareness has been reinforced positively their entire lives, and indeed puppies and young dogs that do not demonstrate a natural affinity and awareness of their handler are often excluded from continuing on as assistance dogs. Given this reliance on human body language, asking a dog to use an interface without guidance is non-trivial and needs to be gradually achieved by building up the dog's confidence. Many of the dogs in our research at some point showed hesitation to leave the sight-line of their handler during training. Training tasks where a dog must leave the room or go around a corner are considered to be harder than those where a dog can still see their handler doing the exact same task. This reluctance to leave a human handler is echoed in other canine interface work (Valentin et al., 2016).

The system we built, in certain environments, necessitates that a dog must go to a different room or leave the sight-line of their handler, in a moment of high stress. On account of assistance dogs' preferred proximity to their handlers, future work with emergency canine remote communication systems may consider focusing on devices worn by the handler, or multiple devices distributed around the household such that the environment is "covered" and a dog can always stay close to their owner to use one of the devices. These kinds of requirements have obvious implications for the system design. For our system, having only one unit in a home that was mounted implied a potential greater challenge for the dog for the reasons just discussed. The majority of canine interfaces for assistance dogs, military dogs, and search and rescue dogs are worn on the dog, so the issue does not arise. However, interfaces worn on the dog are not always desirable or practical, and at the time of this publication, usually involve some sort of interference with the dog (such as a headpiece or vest).

Recently, specific work has been done to address the challenges of wearable computing for dogs. Georgia Tech (Valentin et al., 2015) has recently done work looking at design issues surrounding wearable computing for dogs. As technological components are becoming smaller, and sensors less obtrusive, the potential of computing-enhanced canine wearables such as collars and harnesses is increasing. Fit is more challenging for a harness than for a collar, and harder to accommodate different body shapes of dogs (Valentin et al., 2015). At present point, there exist collars and harnesses that can monitor dogs non-invasively or enable them to communicate remotely with humans. However, to date it is more challenging to have a wearable interface remain relatively obtrusive (due to the added number of components such as tug-able attachments or buttons) and unsuitable to be worn constantly as an assistance dog would have to do.

Even assuming that harness interfaces became increasingly unobtrusive and practical to wear, it is not reasonable to always expect a dog to be wearing an interface when the need to use the interface cannot be predicted. For working dogs that have designated times they are at work, this may be less of an issue. For example, a search and rescue dog may wear a specific vest while searching open fields for a person, and then that vest is simply removed when the dog is done working. However, for assistance dogs, who are often “on the job” most of their waking hours, a harness or wearable with a significant amount of kit is far less realistic to expect that the dog would wear it all the time. If the dog cannot wear it all the time, then it becomes an issue of predicting when the dog would need to have it on, but in the case of unexpected emergencies, this is not possible.

9.2 Re-visiting the Research Questions

At the beginning of this work, we considered the example of Paula and Buddy, where Paula has become incapacitated and Buddy is left powerless to help:

Figure 9.3. Buddy and Paula without a technological intervention.

We then envisioned an alarm that Buddy or dogs like him could use, which led us to ask:

RQ1) How should an alarm be designed to be usable by assistance dogs and provide them with the best possible support for the critical task of dealing with an emergency on behalf of their assisted human? In particular, what design features and interaction mechanisms might help dog users learn how to effectively engage with the technology at the right time? Can HCI design principles and goals commonly referred to when designing interactive systems for human users help design for canine users?

RQ2) How should interaction designers proceed with designing technology for a user of a different species? In particular, given interspecies differences and communication barriers between canine users and human designers, how can the latter ensure that what they design is indeed usable by the former? Can we draw upon existing HCI methodologies, such as user-centred and participatory design, to facilitate the design process and achieve specific design goals?

Our research journey has shown that Buddy can be empowered by technology. We discuss some implied answers to these questions in §9.3 and §9.4, respectively.

Figure 9.4. Buddy and Paula after a technological intervention.

9.3 Design Contributions

This work, situated within the ACI landscape, has aimed to contribute both practically, in terms of design solutions, and methodologically, in terms of research solutions. Here we review the specific design contributions that arise from this work. These address a specific real-world problem and offer a starting point for researchers seeking to design canine emergency communication interfaces in future.

9.3.1 The tug-and-detach / bite-and-pull interface

While there are many categories of basic interaction modes for dogs, this work did not cover them all. By basic interaction mode, we mean different categories of interface. For example, a button interface would be one general category, whereas a sound-activated interface (i.e., activated by barking) would be another. Obviously, different modalities of interaction that were ruled out earlier in our work may have uses in certain contexts. This work was not intended to be a survey of all possible modes of interaction for dogs. Rather, we sought to identify one particularly successful way for the dogs to interact with a technological system, such that they could easily activate it and also learn to use it easily. Other interaction methods may also be successful, but this work has shown how for reasons outlined throughout, a tug-and-detach interface is an ideal design for many assistance dogs.

As we have seen, tug-and-detach interfaces' primary strengths for dog users are as follows:

1) *The dogs in our studies appeared to find gripping something in their mouth and pulling on it a very easy, even pleasurable, thing to do.*
2) *Hence, the dogs in our studies learned to interact with the device very quickly (relative to other tasks they have learned or were asked to learn)- likely because the interface capitalises on a pre-existing affordance mapping for dogs (that certain objects "ask" to be pulled by dogs).*
3) *Many assistance dogs are already trained to retrieve objects similar to the attachments of a tug-and-detach interface (such as bringsels and blood-test-kits).*
4) *Some of the dogs in our studies had already been taught to pull on human alarm cords, with limited success, as they often kept pulling rather than let go after an initial tug, thus breaking the alarm. Hence, a detaching element becomes helpful and even essential.*
5) *The detachment of the tug seems to work as a form of unambiguous feedback for the dogs. This is essential to communicate to them that they have successfully engaged with the interface and their task is therefore complete.*
6) *Lastly, as part of situated training practices that are necessary to teach the dog not only how to use an emergency interface, but when to use it, the detachable tuggy component is*

immensely helpful in the training process as it allows the trainers to know when to reward the dog for activating the system.

Tug-and-detach interfaces are not guaranteed to work for all dog users any more than any interface type is guaranteed to work for any one individual human user. However, for the reasons outlined above, this type of interface shows great promise for future applications.

9.3.2 Effect of materials and resistance for detaching interface component

This work has also identified different reactions in dog users based on different types of tugging components used for the tug-and-detach interfaces described above. Physically, dog toys and bringsels both can vary in material and size, which in turn, different dogs have different preferences for. The dogs in our studies showed an increased play drive when interacting with attachments that were A) fleece or soft B) had tassels or moving parts C) were very similar to toys they already played with. This varied from dog to dog. Importantly, the difference in arousal and interest that these attachments can cause *can be leveraged in the design and training of the dog*. That is, to increase interest and engagement, a trainer may purposely choose an especially toy-like tuggy to start with. Once the dog knows how to engage with the interface, the trainer may then substitute the toy-like tuggy with a less-enticing one so that the dog only becomes interested in it when they are cued, or so that the trainer can manage arousal levels in training sessions.

Similarly, the resistance at which the interfaces are set to detach influences the arousal and interaction with some dogs. Tuggies that are likely to stimulate a dog's exuberance can be paired with higher-resistance triggers. Conversely, a tuggy that a dog may be less enthusiastic about may be paired with a lower-resistance trigger to account for this. Indeed, lower resistance and less appealing attachments may be necessary depending on the personality and training of the particular dog user. This is not a one size fits all, thus an interface where the trigger has different resistance settings and tuggy types is helpful, however a medium resistance setting and toy-like tuggy did work for all the participating dogs following appropriate training.

9.4 Methodological Contributions

In shifting from designing *for* an animal user, to designing *with* the animal user, as discussed above, it is necessary to explore research methodologies that combine established interaction design practice and animal behaviour methods to support interdisciplinary research such as ACI. Here we discuss some methodological implications of this work in relation to the direct involvement of animal users in the design process with participatory design methods.

9.4.1 Using Talk-aloud methods with Canine Participants and Trainers

Our first study (Chapter 4) exploited participating dog trainers' talk-aloud communication during the training process that allowed for real-time interpretation of canine behaviour. Each study phase that involved canine participants directly then continued to leverage this method. In this way, researchers that are not well-versed in canine behaviour can have experts "translate" a canine's experience in real time. This allows the researcher to better focus their attention in the moment and to drive the sessions accordingly. If all interpretation of the canine user's experience was done retrospectively through video or audio analysis, or at the end of sessions, the researcher would not be able to follow the interactions as they are occurring, nor would they be as well situated to direct sessions making appropriate decisions about prototypes configurations for testing based on what they observe.

Thus, with regards to the broader research question of how to design with animal users in ACI, this work suggests that partly relying on human experts as relator and translator of the animal participant's experience is a promising method. This is not without potential flaws, however, such as the expert misinterpreting, or projecting onto the animal participant. The risk of misinterpretation could be lessened by working with multiple experts interpreting, or when triangulating the data thus obtained with other data, such as biometrics.

9.4.2 Using Rapid Physical Prototyping with canine participants

During the studies described in Chapter 6, we found that rough, modular, permutable, thus easily modifiable 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. As we have seen, 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 emphasise the possibility of quickly, easily and systematically modifying the physical prototypes in response to the dog's reactions, in order to maintain the *flow of the conversation*.

Used in conjunction with the method described above, this method allows for dynamic requirement gathering studies or usability testing: if one of the prototyping configurations or aspect of it elicit a certain response in an animal participant, the trainer (or owner, behaviourist, or other expert) can immediately vocalise to the designer their observations and the designer can quickly change design configuration if necessary. For example, if a new participant is introduced to test a button-based prototype, but the dog shows aversion to using the paws with an interface, the designer can change design configuration to adjust the prototype's mode of interaction to make it more agreeable for the dog (e.g. barking, nose-touch screen). This can help discern whether it is the context and training task that the dog is not engaging with, or the interface itself.

9.4.3 Lab and In-The Wild Evaluation with canine users

As with much other research in HCI, our findings highlight the importance of conducting in-the-wild evaluation as well as in-lab testing, as it is upon deployment in the application context that the scope for errors and failure increases significantly. This is especially the case in the case of canine users, for whom evaluation in naturalistic settings introduces new variables and provides insight as to whether findings from lab-based training and learning sessions can translate to the user experience of assistance dogs in the home environment. Our home evaluation allowed us to see beyond the basic interaction of the dog with a certain type of interface, and see more nuanced effects of introducing such a system into a home environment, which had positive impact on the social dynamics and satisfaction of the users and their friends and family.

9.5 Limitations

Of particular concern to many design practitioners is the practical problem of identifying generic design solutions from the situated and highly particularised and often-complex descriptions of social interaction provided by ethnographers [Hughes 1994]. Researchers are exploring a number of potential solutions to this problem, placing particular emphasis on the need to support communication and cooperation between ethnographers and designers in the process of abstraction and generalisation. This research stands as exploratory work that does not provide statistically significant results. However, it has provided an in-depth exploration of the problems that face many assistance dogs and their handlers, providing rich examples of the context in which a canine emergency alarm may be used to significantly impact and even save lives. As we relied on a limited number of participants we were not able to have a broad range of dogs represented. Future work is needed to see if such results can be re-created with other assistance dogs with different training or breed backgrounds.

9.6 Further Work

Further work on canine emergency communication systems is merited based on these preliminary findings. Indeed, our initial findings strongly indicate a need for many individuals (that have assistance dogs) to have a robust, easy to use device that allows the dog to potentially save their life. This work strongly implies that, for many assistance dogs, a tug-and-detach interface is ideal in this situation. However, as discussed, further work will need to consider that many assistance dogs do not like to be out of sight of their handler. The tension between wearable and non-wearable for such systems should be further explored, as should particular design elements of each type of system. Researchers should continue to explore other modes of interaction, both wearable and non-wearable. Further work is also needed to determine if telemetric or other non-invasive forms of monitoring could be an alternative that serves a similar function to canine-activated systems, or could be used in coordination with a system like the one developed here.

9.7 Chapter Summary

In this chapter, we reflected upon the findings of the five studies carried out as a part of this research and situated the work among outstanding issues and questions in ACI, using these findings as a basis to revisit the research questions originally posed in this thesis and to highlight design and methodological contributions to the field. In our next and final chapter, we will briefly review this thesis and comment on future work.

10

Conclusion

In this final chapter, we briefly review the research journey, re-highlight contributions, and discuss potential future work.

10.1 Summary of Work

We have drawn from user-centred design research with assistance dog-human partnerships to develop a system to enable assistance dogs to call for remote help when their owner becomes incapacitated and is unable to do so themselves. 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 formulate informed and individualistic designs. Whilst this research has focused on the specific example of canine users called Medical Alert Assistance Dogs, 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 behavioural observation, our research approach critically questions and reflects upon the way in which dogs can participate in iterative interaction design processes. Our research thereby has sought to address the core questions of what it means to design with animals as a part of ACI's wider research agenda.

To achieve our research aims, we did as follows:

In our first study, we conducted an initial exploration of daily challenges and tasks that scent detection and assistance dogs are expected to carry out, and investigated ways technology might support them in these tasks. We identified that sometimes assistance dogs, particularly MAADs, find themselves alone with an incapacitated handler, and technological interventions may be able to help both assistance dogs and their handlers in these situations.

In our second study, having identified the need for an emergency canine communication system, we gathered specific requirements for such a system by collecting data from real assistance dog partnerships. Using this data, combined with basic information on canine biology and cognition, we came up with several initial potential designs.

In our third study, we took these potential designs and narrowed them down to a shortlist that we then presented to actual dogs and their trainers and observed their interactions.

In our fourth study, we took the data from these initial rapid prototyping sessions to inform the design of our initial high-fidelity prototype. With these prototypes we conducted more situated testing with two dogs in a lab environment, further refining the design based on the human and dog feedback.

In our fifth and final study, we took the final version of our prototype evaluated it in home environments with some of the real assistance dog partnerships that were interviewed in our requirements (second) study.

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. 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.

10.2 Final Reflections

This thesis sought to contribute to the body of knowledge and provide a point of reference for future work with assistance dogs and emergency situations, and canine users that have a need to communicate or accomplish something through use of an interface. We have found that informed, flexible designs can facilitate quick learning of novel interfaces, and that working directly with animal experts is an effective way of practicing participatory design with animal users. We hope that the ideas, observations and reflections presented in this thesis will inspire further practical work and methodical approaches in the canine design realm.

It has provided a first attempt at developing a canine emergency communication system that considers the dogs needs as a user central. Parallel to this work, other projects have also started to look at ways that working canines, and especially assistance dogs and search and rescue dogs, can use emergency communication systems as well. This thesis contributes to the understanding of what situations a certain subset of assistance dogs face (Medical Alert Assistance Dogs, or MAADs), and how one might approach designing a system for them to use in such situations. Combined with other work in the field, a picture is beginning to form showing us that designers must consider new paradigms for the canine users and continue to evaluate strengths and weaknesses in different methodological approaches.

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Appendix A: Pet technologies

The following are pet technologies available for purchase, or in development for purchase, available on market as of December 2016. This is not a comprehensive list; but rather, a sample of what is available. (*) Denotes a product still in development.

A.1. Pet Camera/Monitoring Systems

Product Name	Two-way?	Treat dispensing?	Mounting
Clever Dog Smart	yes	no	floor or table
Furbo	yes (notifications)	yes	floor
Motorola Scout HD 2300	yes	no	any
Pawbo	yes	yes, also laser	no
PetBot	no	yes	floor
Pet Chatz HD	yes	yes, also scent	wall
Petcube	no	no, but has laser	floor or table
Petzi	no	yes	wall

A.2. Programmable Pet Feeding Systems

Product Name	Phone control?	Camera?
Cat's Pad	notifications only	no
Feed and Go Smart Pet Feeder	yes	no
easyFeed*	yes	yes
SureFeed Microchip Pet Feeder	no (pet microchip controlled)	no
PetNet SmartFeeder Automatic	yes	yes

A.3. Telemetric Wearables and Smart Collars

Product Name	Real-time GPS tracking?	Feature notes
Fitbark	no	long battery life
Pod	yes	
Nuzzle	yes	
petTracer*	yes	ultra-light for cats
Buddy*	yes	
Whistle	yes	
Voyce	no	advanced sensor data
Dog Tracker Plus	yes	
WUF	yes	
Tractive	yes	
Garmin	yes	training device
PawTrax	yes	lightweight for cats
Retrieva	yes	

A.4. Interactive computerised toys

Product Name	Remote?	Description
Playdate Ball Camera*	yes	World's first "smart ball" played remotely from phone
GoBone	yes	Bone-shaped rolling toy, movement controlled from phone
iFetch Interactive Ball Launcher	no	Launches tennis balls automatically when dog drops ball in top
PupPod	yes	Kong/wobbler shaped treat-dispensing toy controlled remotely from phone

Appendix B: Consent forms and ethics approval

B.1: Study consent form

Medical Alert Dog Study Consent Form

Thank you for expressing an interest in taking part in our study of medical alert dogs. The ACI (Animal-Computer Interaction) lab at Open University is developing technology to help these working dogs perform their daily tasks and communicate with their handlers. We are researching the dynamics of medical alert dog-client partnerships, in order to identify specific needs for these unique situations.

Your involvement provides an opportunity to help shape technologies being developed to serve the medical detection dog community. The more we can understand the training, needs, and relationships of medical alert dogs, the better position we are in to develop technology to assist them. Specifically, we are designing a prototype for a system of an emergency alert device for the dogs themselves to use to alert friends and family of a problem. This device would be an ‘alarm button’ of sorts for dogs to use should their owner fall unconscious or be unable to call for help.

As a part of the study, we will conduct interviews and observe clients at various stages in the process of applying for and owning a medical alert dog. Your involvement will vary depending on where you are in this process. We may ask you questions regarding your needs, expectations, and experiences in having a chronic health condition and interacting with a dog as a working member of the family. So that we can study alert dogs behaviour, with your permission we may take footage of your dogs continued training and/or alerting. Should any pictures be of interest for publication, we will only publish with your permission.

Any data collected will be securely stored and accessed only by the researchers involved in this research and protected by confidentiality according to The Open University's highest privacy protection standards. We will share with you the findings of this research to allow you to express any concerns you might have and to ensure that these are properly addressed before any findings are published. With your permission we might wish to publish anonymised pictures or videos taken during training or work sessions. For this purpose, we will contact you through the Medical Detection Dogs client liaison.

Alternatively, if you are happy to give us your email address or telephone number, we can contact you directly. In this case, your contact details will be stored separately from any other data. Any published data will be fully anonymised.

This study will fully comply with the Open University's Animal-Computer Interaction (ACI) Research Ethics Protocol, a copy of which will be provided to you along with this paper. At all times we will interact with your dog(s) under your supervision and should you at any time raise any concerns, we will immediately stop any interaction with your dog/s. You owe me no explanation should you wish to withdraw you and/or your dog/s' participation from this research altogether and request that your data be destroyed.

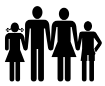
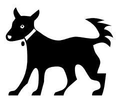
If you are happy to participate in this research, and, their legal guardian, you are happy for your dog/s to take part in this research, please sign this form (on your behalf and on behalf of your dog/s) and return it myself. By signing this form, you are confirming you have been given a copy of the ACI Ethics Protocol.

I have read and understand the above and would like to participate in this study:

Charlotte Robinson

Animal Computer Interaction Lab, Department of Computing, The Open University

Walton Hall, Milton Keynes, MK7 6AA

 Names of any human participants	 Names of any canine participants	Signatures (*a human adult please sign on behalf on any human participants under 18 and any canine participants*)

B.2: Participant recruitment email

Open University: Medical Detection Dog Study Email

The ACI (Animal-Computer Interaction) lab at Open University is looking at developing technology to aid medical detection dogs in performing their daily tasks and communicating with their handlers. We are looking for participants for a research project that looks at how medical alert dogs and their human client work together, in order to better understand the specific needs for these unique partnerships.

We are interested in speaking with individuals and families that are either currently placed with a medical detection dog or interested in getting one in the future. Specifically, we would like to interview and/or observe training sessions or visit clients at home to observe communication between clients and their dogs.

If you think you might be interested in the study, we would love to hear from you. Your involvement provides an opportunity to help shape technologies being developed to serve the medical detection dog community.

For more information please visit:

http://crc.open.ac.uk/Themes/ACI

http://www.open.ac.uk/blogs/ACI

Or contact:

Charlotte Robinson

Charlotte.Robinson@open.ac.uk

B.3: HREC risk checklist document

Human Research Ethics Committee (HREC)
Project Registration and Risk Checklist

If you are planning a research project that involves human participants (data and/or biological samples), you should complete and submit this checklist so that the HREC Chair can decide the level of ethics review that is required. If you have not already done so, refer to the ***OU Ethics Principles for Research involving Human Participants***.

Once you have completed the checklist, save it for your records and email a copy to Research-REC-Review@open.ac.uk, with any relevant documents e.g. a questionnaire, consent form, publicity leaflet and/or a draft bid. You will then be contacted as to whether or not your research will need full HREC review (please indicate if you require a decision very urgently). No potential participants should be approached to take part in any research until you have submitted your checklist and, where required, gained HREC approval (http://www.open.ac.uk/research/ethics/human.shtml#approval).

Section I: Project Details

Project title	Developing An Emergency Alarm System for Diabetic Alert Dogs
Brief description (100 words maximum)	This research project will focus on designing technologies for working canines to use to assist them in their jobs. We specifically wish to design a preliminary prototype for diabetic alert dogs to use to communicate with their owners. Diabetic alert dogs are trained to alert when they detect low blood sugar, which is up to 30 minutes before the client themselves will notice physical signs. This "alert" provided by the dog can be potentially life-saving and improve overall quality of life. Our future research will explore how existing training aids be technologically enhanced to give canines improved capabilities, such as the ability to sound an alarm.
Is your research part of an application for external funding?	No
If so, please provide the name of the funding body and your Grants and Contracts RED form reference number	Funding body: N/A Red form ref: N/A
Will your research proceed if external funding is not awarded?	N/A
Is your research being assessed by the Student Research Project Panel?	No

Section II: Applicant Details

Name of Primary Investigator (or research student) Other researcher(s)	Charlotte Robinson N/A
Status	Full-time PhD student
Email address	Charlotte.Robinson@open.ac.uk
Academic unit	MCT
Telephone number	07530574725
Date	September 2 2013

Section III: For students only:

EdD/MA/MPhil/MRes/PhD	PhD
Supervisor's name	Dr. Clara Mancini and Dr. Janet van der Linden
Supervisor's email address (Your supervisor will need to email their endorsement before or at the same time this checklist is submitted)	c.mancini@open.ac.uk and j.vanderlinden@open.ac.uk

Section IV: Risk Checklist

Please assess your research using the following questions and click yes or no as appropriate. If there is any possibility of significant risk please tick yes. Even if your list contains all "no"s you should still return your completed checklist so the Chair can assess the proposed research.

		Yes	No
1	Does the study involve participants who are particularly vulnerable or unable to give informed consent? (e.g. children, people with learning disabilities)	X	
2	Will the study require the co-operation of a gatekeeper for initial access to the groups or individuals to be recruited? (e.g. students at school, members of a self-help group, residents of nursing home)	X	
3	Will it be necessary for participants to take part in the study without their knowledge and consent at the time? (e.g. covert observation of people in non-public places)		X
4	Will the study involve discussion of sensitive topics (e.g. sexual activity, drug use)?		X
5	Are drugs, placebos or other substances (e.g. food substances, vitamins) to be administered to the study participants or will the study involve invasive, intrusive or potentially harmful procedure of any kinds?		X
6	Is pain or more than mild discomfort likely to result from the study?		X

7	Could the study induce psychological stress or anxiety or cause harm or negative consequences beyond the risks encountered in normal life?		X
8	Will the study involve prolonged or repetitive testing?		X
9	Will financial inducements (other than reasonable expenses and compensation for time) be offered to participants?		X
10	Will the study involve recruitment of patients or staff through the NHS or the use of NHS data?		X
11	Will the study involve the collection of human tissue or other human biological samples?		X

If you answered 'yes' to questions **10** or **11**, you will also have to submit an application to an appropriate National Research Ethics Service ethics committee (http://www.nres.npsa.nhs.uk/).

Please note that it is your responsibility to follow the University's ***Code Of Practice for Research and Those Conducting Research*** and the ***Ethics Principles for Research involving Human Participants***, and any relevant academic or professional guidelines in the conduct of your study. This includes providing appropriate information sheets and consent forms, and ensuring security in the storage and use of data. The Research Ethics website provides further information and guidance.

Appendix C: Participant Interview Questions

These questions were used as a guideline only. If, during the interview, the conversation between the participant and interviewer flowed naturally, then questions were asked in different orders or as part of a natural conversation.

C.1. First (introductory) interview questions:

1. *How old is your dog?*
2. *How long have you had your dog?*
3. *How does your dog alert?*
4. *How did your dog get its name?*
5. *What is your favourite thing about your dog?*
6. *Do you mind telling me what exactly your medical condition is and how it affects you?*
7. *How has having your dog changed your life?*
8. *Can you walk me through a normal day for you and your dog?*
9. *Can you give me some examples of tasks your dog found easier to learn than others? Or ones he has found especially hard?*
10. *How does the rest of your family get along with your dog?*
11. *What sort of responses from your dog do you get when you feel poorly?*
12. *Are you into technology? What sort of a role does technology play in your life?*

C.2 Follow-up interview:

1. *How many non-routine medical incidents have occurred since we last visited?*
2. *What training challenges, if any, have you faced with your dog?*
3. *If you feel comfortable, can you tell me in detail about the scariest medical incident you've had, both before and after you got your dog?*
4. *Is there anything you wish your dog could do or use that could help you both?*
5. *Are you interested in participating in some testing for an emergency canine alarm device?*