Problematising Upstream Technology through Speculative Design: The Case of Quantified Cats and Dogs

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ABSTRACT
There is growing interest in technology that quantifies aspects of our lives. This paper draws on critical practice and speculative design to explore, question and problematise the ultimate consequences of such technology using the quantification of companion animals (pets) as a case study. We apply the concept of 'moving upstream' to study such technology and use a qualitative research approach in which both pet owners, and animal behavioural experts, were presented with, and asked to discuss, speculative designs for pet quantification applications, the design of which were extrapolated from contemporary trends. Our findings indicate a strong desire among pet owners for technology that has little scientific justification, whilst our experts caution that the use of technology to augment human-animal communication has the potential to disimprove animal welfare, undermine human-animal bonds, and create human-human conflicts. Our discussion informs wider debates regarding quantification technology.

Author Keywords
Personal informatics; critical design; design fiction; animal-computer interaction; the Quantified Dog.

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

INTRODUCTION
HCI, as a discipline, is increasingly concerned with the wider social and cultural implications of design practice [5, 6]. Dunne and Raby [14] argue that design as critique, through practices such as speculative design, can be valuable in the problematisation of technologies. They suggest that by "moving upstream and exploring ideas before they become products…designers can look into the possible consequences of technological applications before they happen" [14]. This paper uses the perspectives of critical and speculative design in order to explore an area of near-future/upstream technology that is of substantial interest to both commercial developers and researchers – the "quantification of everything" via the deployment of technology that quantifies multiple aspects of our lives.

Consumers now have access to a plethora of interactive web and mobile apps, often coupled with sensors, which can facilitate the casual collection, aggregation, visualization and sharing of data about *the self*. As observed in [48], technology has been available to measure e.g. "sleep, exercise, sex food, mood, location, alertness, productivity and even spiritual wellbeing" for quite some time. Engagement with such self-tracking and monitoring is part of an inter-related set of practices variously labelled as personal informatics and the quantified-self. These labels emphasize that it is *the self* that is the object under scrutiny, however it is also apparent that consumers will soon have access to technology that can also track, measure, log and interpret the behaviour of not only the self but of the *people* and *things* that are important to them and that surround them in their everyday lives; this could, for instance, include their partners and children [35, 43], their elderly relatives [7], homes [12] and pets [16].

The deployment of quantifying technology has widely-claimed, and far-reaching, positive outcomes and benefits both for individuals and society [48, 25]. Indeed, the HCI and ubicomp communities continue to play a leading role in determining the direction of research in this area e.g. as is evidenced through a continuous rolling schedule of workshops such as [24, 31]. Through these workshops, and a growing body of published work, it is evident that there is sustained research interest, generally, in the technical, user-centred and privacy issues raised by the proliferation of personal tracking technology. However, there is limited existing research by the HCI, or indeed any, research community, that takes a more critical perspective on the design of tracking and quantifying technologies, and that, for instance, challenges the positivist assumptions about its longer term implications.

In this paper we present a case study that takes a critical approach towards the understanding of the implications of the increasing prevalence, and unquestioning acceptance, of

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consumer technology that quantifies aspects of our lives. We use speculative designs to investigate this technological movement and attempt to understand its impact – intentioned and otherwise - on people and society. Specifically, we investigate the potential effects of collecting and quantifying physiological, emotional and behavioural data from companion animals (i.e. pets) and the integration, and sharing, of this data within apps and other services. We are motivated in our choice of this case study by the volume of emerging commercial technology for companion animals as well as that currently in development and offered to early adopters via crowd-funding platforms. Moreover, the developers, as well as third party app providers, of such technology are, doubtlessly, aware of the massive potential market for pet products (estimated at over US$58 billion in 2014 in the US alone [2]).

In studying quantifying technology for companion animals we sought to understand whether this is indeed technology that users want to use in the short term (regardless of push from commercial developers and providers) but also, and more significantly, whether those same users had considered the implications and impact of such technology on themselves, on their companion animals, on the human-animal relationship and on the people around them and even on wider society. We then sought to understand the broader implications of these findings for designers, developers and the HCI research community.

RELATED WORK

Morozov [33] is the perhaps the most vocal popular critic of developments regarding tracking and quantifying technology; indeed he sweeps many of aspects of the quantified-self into a bin of technological activity which he labels *solutionism* – or the development of technology to "fix problems that don't exist". Though it has been observed [8] that Morozov perhaps is too eager to dismiss obviously provocative research prototypes as long-term commercial solutionism, there is some similar emerging dissent in the HCI community regarding the often overly simplistic approach of quantifying everything, including the assumption that users themselves will find quantified datasets immediately useful [37], and of the dangers of short-term thinking evident when interaction designers simply give users what they outwardly appear to want [45].

The majority of experimental, or design, work by the HCI community around the quantified self however remains surprisingly non-critical. Elsden and Kirk [15] question the lack of long term studies around the quantified self, whilst Choe et al [11] identify 'pitfalls' for early adopter users when engaging with such technology. Scholars from other research communities also seem mostly concerned with privacy issues that such technology might raise as part of larger 'big data' concerns (e.g. see [13, 9]). Two recent studies however do take a genuinely critical approach in this area. Firstly, Khovanskaya et al [22] describe their efforts to understand the implications of gathering personal data through web browsing. By exposing users to 'provocative facts' regarding their browsing behaviour the authors were able to demonstrate the utility of critical approaches in e.g. raising awareness of potentially insidious data mining and control over personal data. Secondly, Lupton [27] presents a critical assessment of the sociocultural implications of apps that facilitate self-tracking of sexual activity; she describes how such apps tend to problematically reduce such activity to mere numbers, and questions the (non) scientific value of the algorithmically determined norms of behaviour in such circumstances. This is an observation, and a line of questioning, which we will return to later.

HCI Research and Companion Animals

There is a long history of product design applied to the human-animal relationship (e.g. see [19]). Researchers in the HCI community (e.g. [42]) are beginning to emphasize the need to consider companion animals as important agents and actors in homes in future technological design research; this has already resulted e.g. in work on digital games for shared human/animal experiences ([47]), and in systems that facilitate remote interactions between pets and their owners [36, 17]. Indeed, a growing movement is beginning to study Animal Computer Interaction (ACI) [28] as a distinct and complementary strand of HCI. ACI advocates a scientific interest in companion animals that informs the design and development of advanced interactive technology that might enhance animal welfare and the human-animal relationship, as well as delivering an understanding of the ethical and welfare concerns arising from such work [29].

Technology and the Human-Animal Bond

In parallel developments there has been an explosion in availability of mobile apps and sensors for pets and their owners. For instance, GPS trackers are commonly available that can provide the means to find wayward dogs (as shown in recent Apple iPhone marketing [3]). However some developers have recognized the potential of providing more enhanced data-logging functionality, thus coupling GPS with accelerometry, and other sensors, so that owners can collect, visualize, and share multimodal data on their pets' behaviour, health and general wellbeing. Perhaps the most advanced systems that are closest to market in this respect are offered by the US-based tech companies Whistle (www.whistle.com) and FitBark (www.fitbark.com). Whistle suggest their product is a "*health tracker for your dog. It attaches to any collar and measures your dog's activities, giving you a new perspective on day-to-day behaviour and long-term trends*" whilst FitBark state that their products enable owners to track their dog's behaviour so that they can "*take better care of them"*. A large number of start-ups and tech firms appear to be developing any number of similar and related products as is evidenced by a recent analysis by Kickstarter [1] themselves which determined that their site hosted well over 1,000 technology projects related to cats and/or dogs.

Though it would be naïve to assume that the developers of such products are not motivated by an enormous potential market [2] it would also be unfair to suggest that they do not also have the welfare of animals and the improvement of the human-animal bond as a goal. Indeed the developers of Whistle, for instance, state that they believe *"a better understanding of our pets' health is critical to strengthening (the human animal bond)"* and they want their products to have *"the power to enrich each pet-owner relationship, and (carry) the potential to add years to every pets' lives"*. FitBark also suggest that *"we created FitBark, to redefine the way we understand our pets – because we want every dog owner to be the best dog parent ever"*. These are worthy goals. However what are the implications of us knowing every aspect of our pets' movement, behaviour and motivations? Will this data allow us positive insight to know when they are unhappy or unwell? Or will such insight have a more detrimental effect on our relationship? To our knowledge, there is simply no existing research that might allow us to directly understand this.

THE CASE OF QUANTIFIED CATS AND DOGS

There is a rich history within HCI of using speculative prototypes and fictional scenarios to gain critical insight into the potential opportunities, challenges and long-term consequences offered by interactive technology [26]. E.g. short fictional vignettes have long been used to describe potential technologies to participants [8, 34], as well as to summarise the findings of studies. Additionally, through the concept of design fiction, HCI has become interested in how *speculation* can inform and question the design process itself [44]. We have even seen recent work which reports on entirely fictional user studies carried out with fictional participants [8]. Diegetic prototyping, the presentation of fictional prototypes located within a coherent fictional narrative, has also been advanced as a research method that is particularly suited for evaluating upstream technology; notably this includes the infamous "Quantified Toilets" at CHI2014 [44]. On a more cautionary note, Holmquist [20] signposts the dangers of carrying out studies on technologies that are not realistic. However, in light of recent thinking on critical design, design fiction and diegetic prototyping, we suggest that speculation and discussion about plausible, but fictional, technology may be one of the most powerful methods for critiquing emergent trends in contemporary technology design.

The method we adopt in this paper is influenced by speculative design and fictional scenarios. We developed a series of speculative prototypes on the theme of quantified cats and dogs; these took the form of websites and physical devices. We invited users to view the websites, to read the marketing narratives and rhetoric, and to examine the prototypes, before discussing with us the product designs, their potential value and long-term implications through a series of semi-structured focus groups that were analysed through a process of inductive thematic analysis.

Materials and Fictional Start-Up

Our prototypes were designed in a series of small iterative workshops; we drew substantially from real quantified pet products in order to generate a collection of plausible near-future concepts. These speculative designs comprised not only the prototype systems but also the wider context in which they might be marketed. A fictional start-up company, "The Quantified Pet", was created to act as contextual frame; the company was described as "a group of designers, technologists & animal lovers". Websites were developed for the company's products; Figure 1 illustrates that these were heavily inspired by the web designs typical of modern start-up and crowd-funding culture. E.g. we made extensive use of HTML 5 parallax scrolling elements, white space, and stylistic photographs of the prototypes using depth-of-field effects. Significant design effort was made regarding the textual narrative and rhetoric of the product pages; carefully friendly and

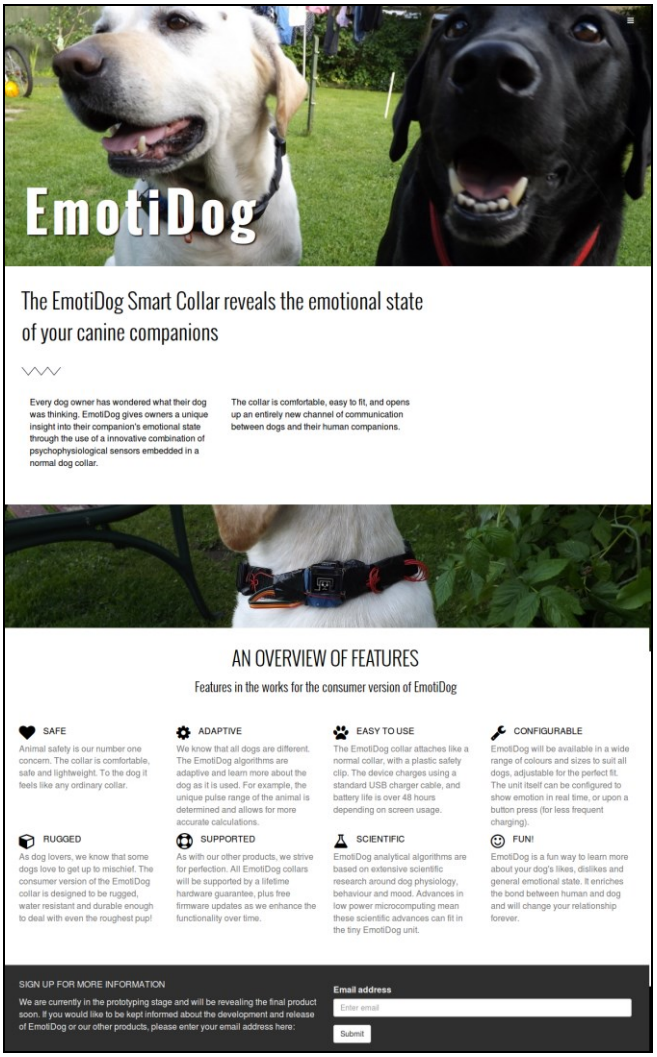


Figure 1 - The product websites drew heavily from typical start-up design aesthetics

optimistic (i.e. techno-utopianist) language expresses the supposed benefits of the technologies, but the actual functionality of the systems are obscured (through the use of "clever algorithms"). The prototypes themselves were built using exposed circuitry and wiring to signify their upstream or "near-future" prototype status, as well as lend plausibility to the promised functionality. Although the products were said to be based on "extensive scientific research" there is no evidence for such statements, echoing standard rhetoric drawn from the start-up aesthetic. This attention to the framing of the prototypes was deemed important in order to convey a coherent narrative of near-future technology. Our three prototypes were: Cat-a-Log, EmotiDog and LitterBug; the (speculative) functionality of each is discussed in detail in the following sub-sections.

Cat-a-Log The Cat-A-Log system is used to track the movement of cats and other micro-chipped animals around your property.

A special wire is buried around the edge of your garden or yard, connected to a box inside the house.

- The wire can detect when pet identification chips pass nearby
- The system uses triangulation to work out the exact location of the animal
- The system requires no special collar attachments, and works with the vast majority of existing identification chips
- The system is completely invisible to the animal, and they do not feel anything during detection
- You can use a website and smartphone app to browse historical maps of your property, viewing movement of all chipped animals within the area.

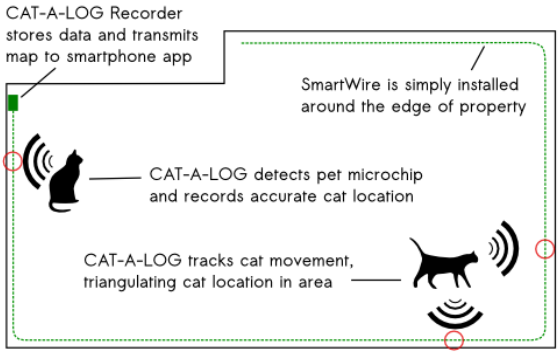


Figure 2 – Example narrative, rhetoric and imagery generated for the Cat-a-Log product.

Cat-a-Log

"Micro-chipping" of pets is a very common practice in the UK, and will become a legal requirement for all dogs from 2016. For dogs and cats it involves a veterinarian implanting a tiny RFID chip usually below the skin of the neck. The unique reference number of the chip is matched with owner information in a national database. The main current use case for the technology is the identification of stray animals. The prevalence of free-roaming micro-chipped cats forms the starting point for the concept of a product that is able to autonomously read these chips. Cat-a-Log (see Figure 2) moves this technology upstream by envisioning a way for chips to be read over distance, in a manner that allows triangulation of location. This is not a typical use-case of this technology, however the individual aspects are based in readily available technologies – cat microchips can be read using particular RFID readers, and "invisible fences" are a readily available technology that use hidden wires to trigger electric shocks using special collars, in order to train animals to stay within particular boundaries. Cat-a-Log exploits awareness of these real technologies to offer a plausible near-future possibility. Cat-a-Log was the only prototype that did not receive a physical implementation. Since the main part of the system is a long wire buried underground, attached to a box, it was felt unnecessary to build a physical representation.

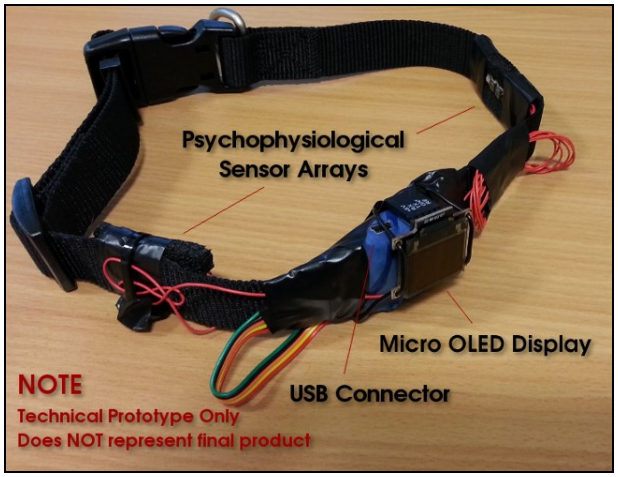
EmotiDog

Given the consumer interest in real products offered by FitBark and Whistle, the design space of the 'quantified dog' has clearly struck a chord with animal owners. EmotiDog is a natural upstream progression of this space. Where existing products tend to monitor and analyse activity to draw conclusions about health, EmotiDog advances the promises of such technology by proposing to monitor dogs' "emotional state" and wellbeing directly. The concept was informed by similar attempts to monitor the emotional state of humans using psychophysiological sensing apparatus (e.g. galvanic skin response). Indeed, the EmotiDog prototype (shown in Figure 3) was a repurposed human monitor wired into an off-the-shelf commercial dog collar. It was therefore constructed using real sensors and electronic components, and leveraged an association with psychophysiological tools in research (e.g. use of the "self-assessment mannequin") to add to its verisimilitude. As such, the EmotiDog prototype was perhaps the most convincing and verisimilar prototype and, as an object, was shared freely with the participants.

Litterbug

The final prototype was Litterbug (see Figure 4), another product aimed at cat owners. The concept again relied on the mystery of cat behaviour whilst out-of-sight of an owner. Where Cat-a-Log builds on the movement-tracking aspect of this mystery, Litterbug is based on understanding *diet*, through automatic analysis of excrement in cat litter trays to identify health issues and track hunting behaviour.

EmotiDog The EmotiDog Smart Collar reveals the emotional state of your canine companions



- Emotidog provides unique insight into a dog's emotional state
- It is a self-contained system integrated into a normal dog collar
- Psychophysiological sensors analyze your dog's emotions
- Emotions are displayed as intuitive emoticons on a micro OLED screen

Figure 3 –the EmotiDog product.

Litterbug is a new and non-intrusive system for monitoring the dietary health and behavior of your cat

- Self-contained system that attaches to your cat's litter tray and uses your home Wi-Fi to upload data
- It uses a unique combination of technologies to monitor the diet of your cat through chemical and odour analysis
- You get to see a comprehensive breakdown and analysis of your cats' dietary behavior and health on our smartphone app and website
- Can act as an early warning system for your cat's health, by detecting symptoms of intestinal health problems; you can receive automatic warnings of symptoms by text

Figure 4 –the Litterbug product.

FOCUS GROUPS

In order to gather user response to our speculative designs, we conducted a series of focus groups. In this section, we describe a (real) study conducted with (real) participants that explores the response to the (speculative) technologies from the perspective of pet owners and animal welfare experts. We deemed the focus group process to be useful for identifying initial reactions to the technologies from both members of the public and animal behaviour experts. These perspectives are valuable for both informing future developments of technologies for use with companion animals, and also for obtaining insight and a deep understanding of how products presented through a typical techno-utopian lens are understood by the public.

Participants and Focus Group Process

We recruited participants on a word-of-mouth basis to help "explore potential technologies for pet owners". We specifically sought participants with experience of cat and dog ownership. Our University has a large, active animal behavioural science research group from which we also recruited a set of experts– with a status of at least postgraduate researcher - to provide a scientifically-informed perspective, primarily on companion animal welfare issues. There were three focus groups, each with four participants (n=12, 10 female and 2 male). Each session lasted around 70 minutes (10 minute intro and 20 minutes allocated to each product). The participants all had experience with pets, including cats (8), dogs (8), reptiles (4), fish (3), mice (3), hamsters (3), rabbits (3), horses (2), guinea pigs (2), birds (2) and chipmunks (1).

We initially asked participants to talk about kinds of quantified-self technologies they had experienced, and more generally about technology they use with their pets. Half of the participants had used quantified-self technology, including pedometers, Wi-Fi-enabled scales, diet tracking apps and mapping tools for tracking runs and training. In terms of technology used with their pets, the participants mostly reported using technology associated with cats. For example, electronic cat flaps to control entry to the house through infra-red or microchip technology, automatic cat feeders, GPS systems to track movement and also products such as laser pointers, DVDs and tablet applications aimed at entertaining cats. Only one participant had used technology with their dog, an "invisible fence" system designed to contain the dog within a specific area. However the participant reported they stopped using it almost immediately due to concerns about animal welfare.

In a semi-structured format, participants were then introduced to each product concept in turn, its prototype (where appropriate) and its website. Participants were then asked to comment openly about their impressions and thoughts as individuals and as a group. In particular, they were asked to discuss any positive and negative effects they might think the technologies might have on the human-animal relationship and how they might imagine using the products themselves and with their own pets (if appropriate). Participants were asked to not be overly concerned about the technical aspects of the prototypes.

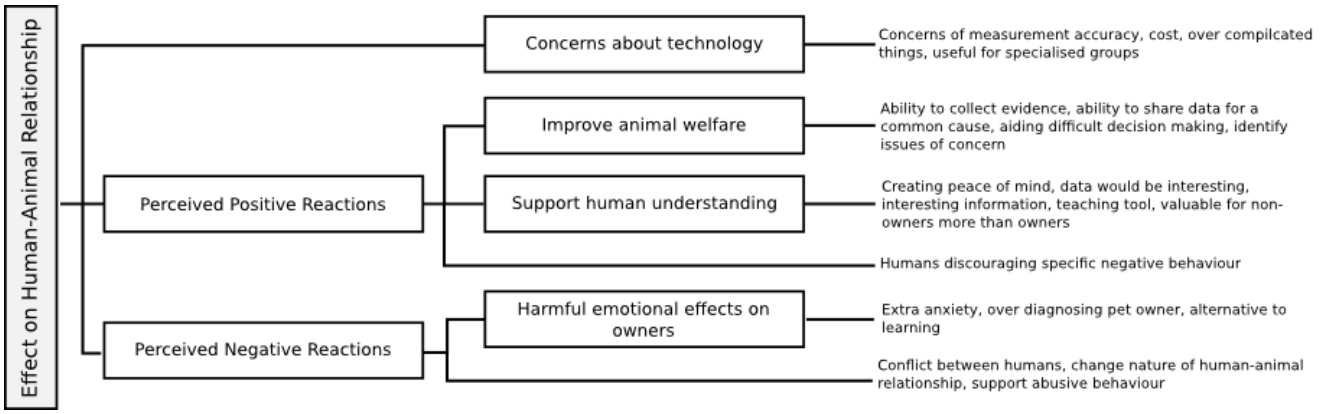


Figure 4: Thematic structure of focus-group data

Data Collection and Analysis

All focus groups were audio-recorded and anonymously transcribed. In a process of inductive thematic analysis, the transcripts of the focus groups were coded by a single researcher who read the transcripts several times, making annotations where appropriate. Category codes were applied to each conversation fragment and in an iterative process were combined and refined, producing 19 categories. To validate this coding, two independent researchers used the coding scheme to categorise a common sample (35%) of the transcript data. Through this process a consensus was reached about the codes emergent through the data. In a series of further iterations, the codes were then compiled into themes and formed into a hierarchy. The thematic structure can be seen in Figure 4. Each theme and sub-theme are discussed in detail in the following section.

FINDINGS AND DISCUSSION

Although the aim of our focus groups was the exploration of prototypes, we were not then specifically interested in gathering requirements, or feedback, as a part of an iterative design process. Instead, our subsequent thematic analysis was centred on exploring the animal-human relationship in terms of new technology more broadly.

Perceived Positive Reactions

The two major themes that emerged were of the perceived positive and negative potential effects on human behaviour around their companion animals. In a positive sense, themes were subdivided into *Improve animal welfare* and *Support human understanding*.

Sub-theme: Improve animal welfare

Sentiment regarding the potential of positive impact on animal welfare featured heavily in the focus group data, with some participants suggesting the ability to collect welfare evidence as being useful: *"the RSPCA* [an animal welfare organisation] *could use it as evidence to show animals that have potentially been cruelly treated."*

The usage of the collected data, and how it would be shared was discussed: *"I'd quite happily have a collar on a dog to see if it was happy or sad and to register with my vet to, say, look at it monthly."* and *"You could demonstrate that you're driving your pet safely."* This suggests the participants would treat the products as a credible source when making decisions, which was emphasised when discussing difficult decision making around health and euthanisation: *"We kept him going until he literally couldn't walk...if we had had one of these collars we could have seen how happy he was"* and *"It might be that when he's on medication it goes up, there's a happy icon [on EmotiDog]. At least then you'd know it's making a difference"*. Using the products as tools to raise issues of concern before they become a problem was also common: *"No one knew the cat had cancer until it went in for an operation and they opened him up and it was apparently ridiculous...[Litterbug] finding something that was curable or at least being able to find out something that at a young age that it would be happening."* and on the use of EmotiDog in kennels/boarding: *"We know ours are happier in kennels than here. They come back looking fantastic, but at the time you'd feel a bit guilty if they were unhappy"*. Interestingly, participants also talked about the potential to improve the welfare of wild animals. For example discouraging or modifying hunting behaviours of cats- *"...if [Litterbug detected] they are eating mice and birds that you change the time of day that you're letting them out, to discourage them."*

Sub-theme: Support human understanding

Participants valued information that creates peace of mind, or reinforces that they are treating their pet appropriately: *"One of the things with cats is they get stuck in sheds…so [Cat-a-Log would] be able to find out", "Sometimes you think is she just barking to protect me. But then sometimes you're not 100% sure...if you knew she wasn't a threat [with EmotiDog], you'd probably be more relaxed"* and *"you can use this say when your dog is at home and you're somewhere else so you know, your dog gets stressed when you leave the house. Or maybe you don't know, it maybe*

calms itself down after 10 minutes after you leave...that would actually be really quite nice to have."

Participants also frequently mentioned that access to the information would simply be desirable, if not actually useful for a specific purpose: *"that would have been a nice thing to know, just what they actually feel when you leave...that would have been interesting knowing what the dogs thought about X looking after them instead of us."* and *"I suppose [Litterbug is] so you can see if they are eating too many mice and birds and everything that I don't actually have to buy so much cat food."* Learning about pet behaviour was also important: *"they can be happy and then suddenly turn round and swipe you one and you think, is it because you're cross and angry...think [EmotiDog] would give a massive insight into why she goes off."*

The potential value in EmotiDog as a teaching tool for young children was a common topic. *"Children can't always read the signals from dogs...and it's a way that the adults can teach the child about dogs.", "if it had a smiley face then children could learn that's what dogs wants"* and *"So if it had a smiley face they'd realise that its fine"*. This also included non-dog owners: *"I think it would be quite useful for children because my little boy likes to stroke dogs...if he had a visual cue that that dog didn't want him near him or didn't want stroking, that would be great"*.

Perceived Negative Reactions

Responses coded within this theme concern the perceived negative impact of quantifying pets. This includes the *Harmful emotional effects on owners* sub-theme. The potential to cause additional conflict between humans and animals was raised as a concern, especially through use of Cat-a-Log by non-owners to potentially support abusive behaviour: "*I personally feel that this is going to get a bit obsessive for people who are going to inflict not so nice things on cats.", "I think this would make [attacks] worse", "If you can identify the cat that's been killing the wildlife in the garden, some people might take quite drastic action and try and kill that cat or threaten the owner. So in a way it identifies the really bad ASBO cats"*. Participants were also worried the technology could create conflict between neighbours– *"you'd worry that people that don't like my cats would say 'I've tracked your cat into my garden… your cat took a shit on MY grass'". "If people were obsessed with their gardens and they knew it was one cat, rather than five or six, they would start on you"*.

Sub-theme: Harmful emotional effects on owners

A strong theme emergent from the data was the concern for harmful emotional effects on owners, most dangerously by using technology as an alternative to learning to identify animal emotions, which has the perceived potential to break down existing methods of human-animal communication: *"I think especially with dogs, they're very attuned to how we interact with them"*, *"Basically you're not really interpreting their behaviour accurately anymore because you're relying on something else"* and *"because you then focus on the emoticon to read the dog's body language and don't focus on what the dog is actually doing."*. Participants also raised concerns around ethics and dangers of potential technical failures *"if you get a smiley face emoticon and the dog is growling at you...you then go to hug the dog you could then get a very serious injury."* and *"If there is just a smiley face all the time and the dog is trying to eat you."*.

This perceived negative effect on human-animal relationships also manifested itself as a concern for pet owners for whom the expanded data may cause extra anxiety: *"People can be absolutely addicted...checking on their dog every two minutes"* and *"You can get so health obsessed that you can break the bond with how you are with them"*. Furthermore, our animal behavioural specialists were worried that it would mean these technologies would create additional conflict between veterinarians and pet owners: *"People always Google first...and they diagnose them with all sorts of weird and wonderful tropical diseases.", "There is the danger that you won't listen to the vet and you try and manage the diet of your cat on your own and get it really wrong"*. This worry is well-founded. Vets were treated with suspicion already – when asked *"would you be more inclined to trust the collar than the vet?"* all participants in one group agreed without hesitation- *"vets do make a lot of money…"*.

Concerns About Technology

This separate category covers concerns raised about the technical implementation, and the feasibility of the products. From the animal behaviour experts, there was immediate concern about the EmotiDog prototype in particular – *"I'm really worried about this product" "has it been validated against any other measure of emotion in dogs?"*. This is an excellent question, however one we only ever received from the animal behaviour experts. Indeed pet owners never questioned the theoretical basis for any of the products. The experts also raised fundamental issues of measuring animal emotions: *"We don't even understand them properly yet, so how can we program a computer to understand a dog or a cat?"* and *"How would you know that you can develop the technology to say that a cat is happy? How do *you* know that?"*. Discussion also covered the over-complication of the pet-owner relationship: *"It would depend on how much it tells you, because I think for basic things you could already see."* and *"It depends how much accuracy it's going to go into. If it's just happy or sad you could probably just tell"*.

IMPLICATIONS

Firstly, our findings have implications for the development of products intended to enhance or improve the human/animal relationship; secondly they also have wider importance regarding the current research and development trend of 'quantifying everything'. We discuss each of these aspects in turn and suggest avenues for further research.

Implications for the Human-Animal Relationship

Our findings suggest that there is a strong, and well-intentioned, desire among owners to better understand the needs of their pets. Our participants acknowledge and regret what they consider to be the limitations of animal-to-human communication. They expressed a wish for improved information about their pets' physiological condition, in order that they might take positive action towards e.g. minimizing suffering and seeking medical attention in a timelier manner. They also expressed a desire to have improved information regarding animals' emotional needs, so that they might make better-informed decisions about welfare, such as whether it is appropriate to leave an animal alone for extended periods of time. These desires, to a large extent, match the intentions claimed by developers of the products we reviewed earlier.

Regardless of the above, there is a wealth of strong evidence (e.g. [32]) that companion animals –especially dogs– have evolved to exhibit powerful cross-species social cognitive abilities whilst, in fact, humans are also skilled at interpreting pet behaviour and psychological state (e.g. [38]), which serves to reinforce bi-directional social bonds and understanding. Furthermore, there is increasing acceptance that dogs and humans co-evolved together to refine this ability [39]. Therefore significant questions need to be raised over whether relatively simple technology can ever usefully enhance, let alone replace, this co-evolved innate ability – despite users suggesting it may be "what they want" [45]. We caution that any move towards substituting the human interpretive aspect of this social relationship with a smartphone and a set of algorithms has potential to genuinely undermine the human-animal relationship. Such a move could potentially reduce the family pet to something akin to a Tamagotchi or a Nintendog, requiring owners to engage in mechanical, gamified, actions likely to fulfil algorithmically determined needs [10]. Haraway [18] appears to warn against this when she insists that cross-species companionship necessarily involves recognizing and considering the complexity of dogs (and humans) and their 'significant otherness'. Moreover, it has long been argued that humans have a genetic need, termed 'biophilia', to connect with animals, nature and the wider natural world [46] and we signpost the work of other researchers, most notably Kahn et al [21], in raising concerns that "actual nature is being replaced with technological nature" in an increasing number of settings and contexts. The similarly techno-utopian vision of wholly 'robotic' pets is also widely pushed by industry and researchers alike, but the societal implications of such technology have also been strongly questioned [41].

A further concern was that participants in our study were fascinated by the utility offered by the prototypes, but displayed little or no concern for how they worked. Indeed, there seems little incentive for pet tech-designers to ensure that interpretations automatically provided by any technology is in accordance with, and limited to, well-established concepts and metrics derived from animal behaviour research. The experts consulted in our study were concerned that the information such technology generates may actually serve to confuse, or worsen, owners' understanding of animal behaviour and therefore, subsequently, create welfare problems for their animals. For example, our experts suggested that children must learn through experience [30] that dogs must be treated with caution and that individual dogs may respond very differently to the same actions. Any technology – such as EmotiDog - that reduces children's tendency for caution around strange dogs could increase the chances of dog bites and, perhaps ultimately, unnecessary euthanisations.

Our findings also highlight the potential for pet quantification technology to create human-human conflict. Participants suggested that the Cat-a-Log system would appeal to people who dislike cats and most especially do not wish them to be encroaching onto their property. There is existing research [4] which demonstrates strength of feeling in non-cat owners regarding roaming behaviour in domestic cats as well as anecdotal evidence of malevolence towards cats which exhibit this behaviour. A system such as Cat-a-Log has the ability to identify individual cats, to notify property owners when a specific cat had entered their garden, to locate specific owners, and to provide a data set with which the aggrieved property owner can confront the pet owner. Another further potential human-human problem is the undermining of trust in the professional opinion of veterinary professionals. A number of participants expressed the opinion that they would like to use the technology to lower the number of visits that they make to the vet. Unless the technology is entirely scientifically accurate, a lowering in frequency of visits to the vet should be seen as a significant concern for animal welfare.

The Quantified Everything

Beyond the human-animal relationship, our study suggests implications for the quantified-self movement more generally. As mentioned, our participants were fascinated by the utility offered by our products, without any concern for how they worked. This issue goes beyond our own case study: if there is little incentive for ensuring a consistent level of scientific accuracy in quantified data interpretation, it seems unlikely that companies would bother to engage in the expensive and time consuming trials necessary to demonstrate this. Indeed, examining descriptions of any quantification technology on crowd-funding websites, it is often unclear which component part (if any) of the technology is a direct implementation of scientific findings, be that the hardware, the measurement strategies, the analysis algorithms, or the interpretation and guidance provided to users. The vague manner in which science is typically discussed by technology companies, means that it is entirely possible to market products that have absolutely no scientific foundation at all. E.g. in our study the concept of interpreting animal emotions greatly appealed to owners

and it would appear that providing such a service could be commercially successful. However, our experts argued that animals do not experience emotions in the human sense; indeed anthropomorphism in itself continues to be a highly contentious topic within the scientific community. Moreover, by relying on technology to guide our decisions, we are not taking advantage of any collective body of human knowledge; instead we may simply be outsourcing our decision-making to a novice programmer who has made their "best guess". This naively simplistic quantification of complex, ever-changing, often qualitative, aspects of lives (often using a sample size of n=1), be this our own sexual performance [27] or the welfare of our pets, seems fraught with problematic outcomes.

Finally, there is a danger that quantification technology has the potential to not only provide inaccurate advice, but also effectively reduce our interest in understanding underlying behavioural processes. In effect, the great danger in outsourcing our knowledge, intelligence and decision making to technology, is that we become less able to live our lives effectively without technology. E.g. an application that tells us *how* to react to a dog, without explaining and teaching us *why*, may be considered genuinely problematic.

Alternative approaches

The goal of our study was to explore hypothesized *future* technology; our intention was to raise awareness of issues with products before they become public concerns, not afterwards. Hence our deliberate approach, motivated by existing (and emerging) HCI research in e.g. speculative design and design fiction; we fully encourage other researchers to utilize similar approaches when considering trends in other technology areas. In the case of quantified cats and dogs, there are a range of alternative approaches that could be used to deepen the understanding of emerging issues. Empirical work with early adopters of commercial products could be undertaken (as in [11]) that generates rich and nuanced datasets from real use, whilst a more participatory approach to the design process could draw in expertise from animal behaviour experts and user groups to generate alternative design thinking.

CONCLUSION

We conducted research to examine attitudes and reactions of companion animal owners and animal behaviour experts towards near-future, or "upstream", technologies, the design of which was extrapolated from trends observed in contemporary products that aim to quantify and interpret animal behaviour and wellbeing. Motivated by [14], and building on recent critical approaches to design in HCI, we explored the potential implications of imminent technological products before they have appeared. Our findings suggest that there is a great appetite and enthusiasm among companion animal owners for technology that aims to improve their understanding of animal behaviour. However, we found that owners were generally unconcerned about the scientific basis upon which the speculative technology made decisions and provided advice. Our animal behaviour experts who took part in the study suggest that such technologies possess the potential to exacerbate existing human-animal problems related to inter-species social communication and cognition, and may actually serve to cause significant new human-human conflicts between pet-owners, citizens and veterinary professions. Although this study was primarily concerned with quantified pet technology, many of the concerns and issues are also of direct relevance to the wider investigation of technology that endeavors to quantify aspects of our lives.

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