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DESIGNING FEATURES FOR FIDO: WHAT MAKES ANIMAL-COMPUTER INTERACTION SO DIFFERENT FROM HUMAN-COMPUTER INTERACTION?

JYVÄSKYLÄN YLIOPISTO
TIETOJENKÄSITTELYTIETEIDEN LAITOS
2013

ABSTRACT

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Designing Features for Fido: What Makes Animal-Computer Interaction So Different From Human-Computer Interaction?
Jyväskylä: University of Jyväskylä, 2013, 21 p.
Information Systems Science, Bachelor's thesis
Supervisor: Kuparinen, Liisa

Animal-computer interaction aims to allow animals to interact not only with computers but their owners and other humans through computerised interfaces.

This thesis studies the existing research on the main characteristics of animal-computer interaction and what sets it apart from human-computer interaction. The main focus is on recognising and defining different kinds of challenges affecting the development of tools and systems for animal-computer interactions, both from technical and ethical point of view. Besides these challenges examples of proposed implementations of animal-computer interaction are presented, outlining some possible technical solutions suggested for different needs, environments and targeted user groups.

As a fairly new area of study, the viewpoints of animal-computer interaction and its possible uses, as well as the driving forces behind the research – even the seriousness of the approach – can be seen to vary greatly. Still, majority of the research is done in the name of promoting the well-being of all different kinds of animals in our lives. The studies show that due to the animals' inability to voice their opinions or consent it is difficult to evaluate the true ethicality of proposed implementations. This also applies for usability and other technical issues surrounding the development of computerised systems for animals communicating in such different ways from human users. Based on the research studied also the true benefit of animal-computer interaction to the animals themselves remains debatable.

Keywords: animals, interaction, wireless communication, ethics, user interfaces, user research

TIIVISTELMÄ

Lehtonen, Jaana
Ratkaisuja Rekulle: Mikä erottaa eläinten ja tietokoneiden välisen vuorovaikutuksen ihmisten ja tietokoneiden välisestä vuorovaikutuksesta?
Jyväskylä: Jyväskylän yliopisto, 2013, 21 s.
Tietojärjestelmätiede, kandidaatin tutkielma
Ohjaaja: Kuparinen, Liisa

Eläinten ja tietokoneiden välinen vuorovaikutus pyrkii mahdollistamaan eläinten vuorovaikutuksen paitsi tietokoneiden kanssa, myös eläinten omistajien tai muiden ihmisten kanssa tietokonevälitteisesti.

Tämä tutkielma tarkastelee olemassa olevaa tutkimusta eläinten ja tietokoneiden välisestä vuorovaikutuksesta, sen pääpiirteistä, sekä niistä tekijöistä, jotka erottavat sen ihmisten ja tietokoneiden välisestä vuorovaikutuksesta. Tutkimuksen pääpaino on erilaisten, eläinten ja tietokoneiden vuorovaikutukseen suunniteltujen, työvälineiden kehitykseen vaikuttavien haasteiden tunnistamisessa ja määrittelyssä sekä teknisestä että eettisestä näkökulmasta tarkasteltuna. Lisäksi esitellään tarkastelluissa lähteissä esitettyjä mahdollisia tapoja hyödyntää eläinten ja tietokoneiden vuorovaikutusta, sekä tämän toteutukseen ehdotettuja teknisiä ratkaisumalleja erilaisten tarpeiden, käyttöympäristöjen ja aiottujen käyttäjäryhmien kannalta.

Vielä melko uutena tutkimusalana eläinten ja tietokoneiden vuorovaikutuksen näkökulmat, ehdotetut käyttökohteet ja tutkimusta ajavat tekijät – jopa vakavuus tutkimukseen asennoitumisessa – vaihtelevat suuresti. Suurin osa tutkimuksesta tehdään silti ihmisten elämässä mukana olevien erilaisten eläinten hyvinvoinnin nimissä. Tutkimuksista on nähtävissä, että eläinten kyvyttömyys ääneen ilmaista mielipiteitään tai suostumustaan osallistumiseen tekee kehitystyön eettisestä arvioinnista hankalaa. Sama pätee myös käytettävyyteen ja muihin teknisiin tekijöihin työssä, jossa suunnittelun kohteena olevien järjestelmien käyttäjät ovat eläimiä, joiden kommunikointitavat eroavat suuresti ihmiskäyttäjistä. Tutkimusten perusteella myös eläinten tietokoneellisen vuorovaikutuksen todelliset hyödyt juuri eläinten kannalta ovat yhä kyseenalaisia.

Asiasanat: eläimet, vuorovaikutus, langaton viestintä, eettisyys, käyttöliittymät, käyttäjätutkimus

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1 INTRODUCTION

Today many, if not most, people already use computerised tools to interact with each other on daily basis. Lately, though, another possible user group has emerged into the limelight with researchers starting to study the possibilities of expanding computer-mediated interaction into the world of animals. As McGrath (2009, p. 2529) states, “if ‘human computer interfaces’ should be designed for ‘anyone, anywhere’, then why not for all species?”

Some implementations to help humans include their pets into the world of Internet communications and social media already exist, such as Dogbook (Dogbook, n.d.), a Facebook and smartphone application letting dog-owners share their pet’s pictures, stories etc. via the dog’s own profile as well as befriend other dogs online. True animal-computer interaction aims much higher than this, though, by for example developing technology designed specifically to animal use and thus enhancing humans’ relationships with the animals in our lives and helping us better understand the workings of animal cognition (Animal-Computer Interaction, n.d.).

This thesis aims to define the main characteristics of animal-computer interaction (ACI) by its possible uses, benefits and technical requirements. The main research problem to address is “What is animal-computer interaction and what characteristics set it apart from human-computer interaction?" This problem will be discussed through the following questions:

- What are the possible implementations of ACI technology?
- What type of challenges lie in expanding the use of computer-mediated interaction from humans to animals?
- Who would benefit from the implementation of animal-computer interaction?

This thesis does not focus on straightforward surveillance and/or tracking systems such as remotely operated cameras and GPS locating, which require no real change in interaction from the animal’s side, i.e. situations in which the animal would act no differently with or without the presence of these computerised tools. The thesis is conducted as a literature review, with main focus being on articles and conference presentations.

In the following chapters different aspects needed to consider in developing technology for animal-computer interaction are presented and discussed. The first chapter explores different ways to use such technology, presents possible target groups for these implementations and gives examples of suggested usage for these groups based on existing studies. The second chapter outlines challenges affecting the development of ACI technologies, focusing on two separate problems: The technical challenges of designing tools not for humans but animals often acting in very different ways from us, as well as the ethical challenges of ensuring the well-being of animals while using such technology and defining the true beneficiaries of these implementations. Both of these aspects need to be addressed for us to be able to build working interactive tools benefiting, at the best, both the human and the animal. Finally in the conclusions the central results of these chapters will be presented.

2 IMPLEMENTATIONS OF ACI TECHNOLOGY

As Tan, Teh and Cheok (2006, p. 1) have stated, current game play interaction with pet owners and their pets mainly consists of simple games in the style of "fetch, toying with a ball of yarn or chasing squeaky rubber toys". But human-animal interaction could become so much more with the help of technology targeted also to animal users: at TED 2013 Diana Reiss, Peter Gabriel, Neil Gershenfeld and Vint Cerf even publicised the idea of an "interspecies Internet", connecting us with not only other human beings, but really the entire planet (TED Blog, 2013a).

Still most of the suggested uses for ACI technology are so far in much smaller scale and more tangible as part of our everyday lives, such as improving our possibilities to interact with our pets even when away from home or enhancing the living conditions of farm animals.

2.1 Target groups

Many of the researchers studying animal-computer interaction seem to be worried of the well-being of pet animals in modern society, where most people spend their days at work away from their pets: For example Lee et al. (2006, p. 301) note that pets are "one of the few things that bring warmness to our hearts and homes" but at the same time Teh and Cheok (2008, p. 26) point out that "city people are too busy to spend time with their pets". Indeed Wingrave, Langston, Rose and LaViola (2010, p. 2662) say it out loud: "today's canine has to compete for a human's time against the distractions of TV, streaming videos, music, gaming, online worlds, social sites and general Internet browsing".

It could be noted that while many pinpoint this fact, only Paldanius, Kärkkäinen, Väänänen-Vainio-Mattila, Juhlin and Häkkilä (2011, p. 2649) were sure to mention that "it is important to notice that the owners do want to spend time with their pets and care for them, and thus the technology developed should support this rather than attempt to automate such practices". In this light it could almost be interpreted that having pets is considered a human right taken for granted and the pet's well-being should be taken into consideration only within this frame.

Luckily Lee et al. (2006) also bring forward another possible use case in the shape of letting allergic people gain the chance of interacting with animals without directly touching them – or anyone visiting a zoo getting the possibility to experience stroking a live, wild animal which otherwise could not be done due to the apparent danger. Their studies indeed show most people prefer touching to other kinds of interaction with their pets. Similarly Teh and Cheok (2008, p. 27) remind how "touch is very essential for both humans and animals": pets can help people feel accepted while also satisfying the very human need to nurture, as well as bring new value to therapeutic settings providing both psychological and neurological benefits.

However, possible use cases exist also outside the world of household pets. Schweller (2012) has witnessed successful use of tablets and other devices by bonobos learning to communicate with humans: plans exist to introduce ways for the apes to control their own environment for example by opening doors and using vending machines as well as to alert security guards when noticing some kind of suspicious activity. Savage et al. (2010) on the other hand propose wearable computers as a way of determining when different cows in a shed are ready to be inseminated. This would not only dramatically reduce the work needed to follow and manually measure possibly thousands of cows, but also save the cows from continuous examination most likely reducing stress and enhancing their well-being. Both results would be well in line with the proposed benefits of animal-computer interaction improving not only the ethical aspects of adding to the well-being of farm animals, but also adding to the economical sustainability within the industry (Animal-Computer Interaction, n.d.).

2.2 Technologies

Different technologies suit the needs of different target groups and their proposed use of ACI technology: different species' living environments as well as their behavioural models differ greatly and what works with one pet living amongst humans might not work with some production animal living with other of its kind on a farm. Here some examples of possible technologies for such uses are presented as based on existing studies on different types on animals and ideas of ACI usage.

2.2.1 Wearables

Wearables are, as the name suggests, computer interfaces which are 'dressed' onto the animal, such as types of harness and clothing. For example Lee et al. (2006) have designed a lightweight jacket for a chicken to wear enabling it to feel the sensation of stroking through the jacket's vibration motors as sent remotely by a human touching a physical doll representing the chicken. At the same time sensors following the chicken send data to the owner's 'office system' allowing her to feel its movement and 'see' the bird moving in its habitat (figure 1).

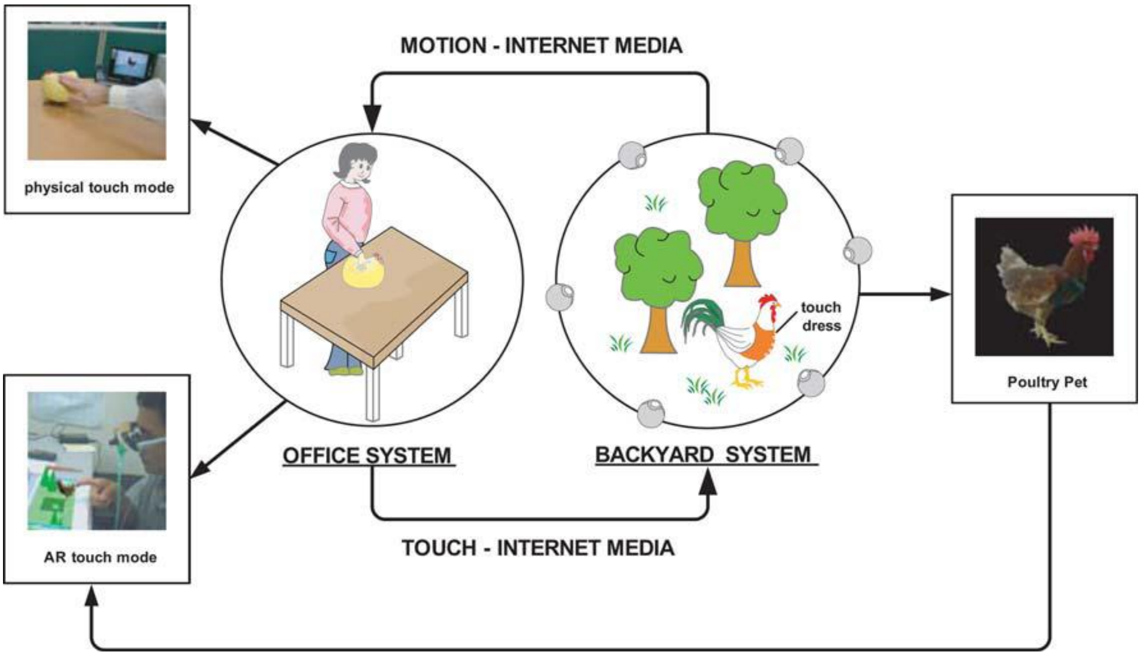

FIGURE 1 Human-poultry interaction system (Lee et al., 2006)

This kind of wearable technology is especially suitable for remotely delivering the sensation of touch towards the animal. As Teh and Cheok (2008, p. 26) write, "tangible interaction provides a very significant meaning for remote interaction between humans and animals", though they also add that "visual communication helps in identifying the communicating subject and understanding the current physical state the subject is in". Still there exist situations where visual information is not available or is hard to obtain – or when 'touch control' would simply add undeniable value to the task at hand. One such example are search and rescue dogs. Lee et al. (2006) point out the existing need for trained dogs to help gain access to confined and possibly dangerous places inaccessible for humans. With wearables these animals could be guided and their movements controlled by remote physical touch, simultaneously getting real-time feedback from the dog through the same system. Savage et al. (2010) extend this idea to include surveillance dogs and guide dogs for blind people. They also suggest that with the help of wearables the animal could perform basic tasks such as feeding itself, while at the same time the computer could collect information on the animal's stress levels.

Naturally, such equipment needs to be implemented in a way that does not hinder the normal activity of the animal. According to McGrath (2009, p. 2532) correctly designed wearables “enable the animal to move and act naturally, while receiving and sending information via computers”. At least the experiments mentioned earlier by Lee et al. (2006) were successful in this sense, showing that the test subject chicken was not irritated by wearing the jacket and acted naturally with it.

2.2.2 Other interfaces

Besides wearables, several other types of interfaces suitable for animal-computer interaction have also been presented. One good example is the Feline Fun Park, an interactive cat entertainment system created to “encourage pet activity as well as engage interaction with the pet’s distant owner” (Young, Young, Greenberg and Sharlin, 2007, p. 1). It is built upon a commercially available ‘cat condo’ which can be activated both by the cat moving in or around it and the owner operating the system remotely via Internet. Different moving objects (such as toy mice and LED lights) placed inside the condo entice the cat to play with it even without the involvement of the owner when set in automatic mode. There is, however, no camera installed, but the owner can monitor the pet’s activity through several input sensors installed in the condo.

In their experiments Young et al. (2007) found the cat’s interest towards playing with the cat condo increase greatly after modifying it into a tangible interface. Still, the importance of the interactive play with the owner remains highly dubious – does the cat actually have any idea it is playing with a human being instead of just another amusing, automated toy?

Tan et al. (2006, pp. 1-2) have designed Metazoa Ludens (figure 2), a new gaming model that “enables playing computer games between humans and animals in a mixed reality environment that gives equal space for all players”. This consists of a playground structure where a hamster can move on a ”mouldable surface creating an elegant yet edgy ever changing organic terrain”, chasing a mechanically driven bait. The movements of the hamster are transferred into a virtual gaming world as a “virtual pet avatar”, running across landscapes equivalent of the surface of the playground. Similarly, in the game world, the pet owner is represented by a human avatar. She can control its movements, which again are transferred back to the hamster’s playground structure and the bait the hamster follows. This results in a virtual representation of the hamster actually chasing after its human owner, “allowing pet owners to play computer games with their pets.”

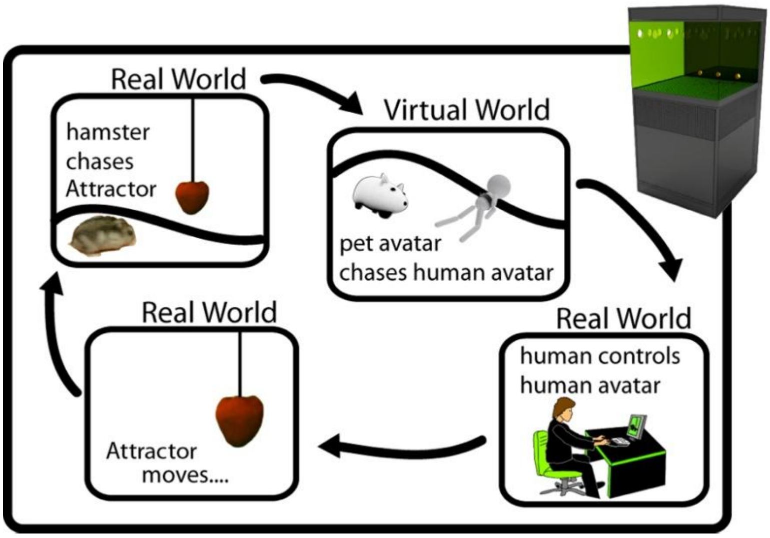

FIGURE 2 Overview of Metazoa Ludens (Tan et al., 2006)

Wingrave et al. (2010, pp. 2662) have conducted experiments on "canine amusement and training" with intentions to "reclaim time for the human-canine bond" while teaching the dogs to act calmly and follow human directions. They too, like the group working on Metazoa Ludens have wanted to make it possible for the animal to "join the human in electronic gaming to produce happy and well-trained canines and humans". In their games the dog is to follow different training cues such as to stay in place or come to their owner, while adding distractions such as sounds of barking, doorbells or other commonly faced sounds. Places to stay are indicated with both paw- and footprints by a computerised projector and the dog's movements are followed by a computer through a makeshift control device in form of a Wiimote (or equivalent) strapped onto their back – this prototype solution setting it apart from 'pure' wearables. True interactivity on the animal's part is somewhat varied, though, as with some tasks it is required from the human to place the dog into the appointed space, making it the dog's task to simply follow the owner's instructions or stay in place where put.

One, rather distant example, of proposed computerised pet interaction is Hello-Fish (Jang & Lee, 2004), which allows people to feel the presence of their pet fish even when away from home. The system follows the fish via a real-time webcam. This video information can be sent via the Internet to the owner's computer where the movement of the fish in a tank is synchronically mapped into a visualisation in the form of an animated wallpaper. Even further, a MIDI device can modify the movement of the fish into music to accompany the wallpaper. The remote connection also allows the owner to feed the fish through the wallpaper's control buttons.

3 CHALLENGES IN ACI DEVELOPMENT

One, rather peculiar, challenge in ACI development is indeed the short history of it, often making it too easy to experiment for the sake of experimenting, lacking a specific need to study and fulfil: Wingrave et al. (2010, p. 2661) acknowledge that "cross-species computer applications have a history of blended science and humor, despite the real potential for improving the canine-human bond". Also Young et al. (2007, p. 4) feel the need to point out that "while papers and videos on this topic are often tongue-in-cheek, our own research is serious".

Here, though, the focus remains in more tangible problems and challenges. They are explored regarding both the technical aspects of building – and assessing the functionality of – tools to be used by and/or with animals rather than people and the ethical questions of evaluating the suitability and need of these systems and their effect on the well-being of possible animal users.

3.1 Technical challenges

According to Schweller (2012, p. 43) the bonobos studied using the touchscreen keyboards are "incredibly good at operating them" and have adapted to all new computer technology the researchers have introduced throughout the years. Earlier, after learning to control the program in use with an off-the-shelf gaming joystick, they quickly progressed to use it for its original purpose in the form of playing computer games such as Pac-Man. Another research team has successfully taught dolphins to use a keyboard to select different objects paired with sounds (TED Blog, 2013b). However, not many animals share the very 'human' traits and behavioural models of for example the bonobos who are deemed "one of humankind's closest living relatives, sharing more than 98% of our DNA" (Bonobo Conservation Initiative, n.d.).

Resner (2001, pp. 18-19) notes that "animals do not read manuals" and therefore "artefacts of an animal-computer interaction must present themselves in an intuitive manner that requires minimal training." He points out animals have cognitive models very different from humans and it is simply unreasonable for dogs to "be expected to understand that pressing a button is the same as interacting with its owner." For humans sharing a language it is easy to give straightforward instructions for completing a task (either verbally or in writing), but this does not work with animals. The lack of common language is what makes it impossible, among other things, to have a meaningful 'conversation' with one's dog over the phone: "Telephones take advantage of a dog's ability to hear, but do not compensate for their inability to speak" (Resner, 2001, p. 32). This means the animal's possible response to recognising its owner's voice made by howling or wagging its tail is lost to us.

By far most computer interactions are, obviously, focused and built on very human-centred functions: language-based interfaces, visual information designed for human sight and physical functions suitable for human hands and skill sets are not very animal-friendly. Some technology could be more suitable to cross these species specific boundaries than others, such as non-language audio, haptic interfaces and different reactive sensors. (McGrath, 2009.) Finding the right tools and suitable cues is important, as Wingrave et al. (2010, p. 2662) point out: "In fact, games that use a computer to mediate the canine-human interaction can lead to anxiety or confusion in canines if not careful."

McGrath (2009, p. 2531) states that "for non-humans to participate, the system must make sense in the participants' world". Still, understanding what kind of cues and designs do work for animals can be difficult. For example, Somppi, Tornqvist, Hanninen, Krause & Vainio (2012, p. 173) have found in their studies that dogs are attracted more to pictures of "conspecific and human faces over inanimate objects". They prefer faces of other dogs above all other categories, while images of letters receive the least number and shortest time of fixation from the dogs, but without further studies it cannot be determined whether dogs actually possess picture object recognition.

All off the non-wearables examples presented here (Feline Fun Park, Metazoa Ludens, Hello-Fish) face the same problem: While the animal successfully interacts with the computer interface such as the cat condo, does it somehow recognise it as such instead of just another pleasing toy without such added functionality? Is the animal consciously interacting with a computer, or even more so, the human being remotely operating it? And if not, does it really matter? The situation is similar with the wearable jacket on a chicken, where it is hard to see whether the chicken can indeed connect the pleasant stroking sensation and some faraway human being doing the actual stroking.

Assessing even the functionality of a computerised interface can be difficult with animals. As Väätäjä (2012, p. 19) points out, with animals there is "no direct way to ask for impressions or descriptions of experience". Instead this needs to be measured in different forms, such as following the reactions and emotions of the animal as well as possible changes in its behaviour. For example Lee et al. (2006) noted the chicken wearing the jacket to be sensitive to the vibrations: when the motors in the jacket were remotely activated the chicken moved its head towards the vibration. Also Wingrave et al. (2010, p. 2668) monitored the behaviour of the test subject dogs while playing. The dogs were noted to experience positive "outbursts during play" as well as be generally portraying positive body language and wagging their tails.

3.2 Ethical challenges

"The welfare of an animal includes its physical and mental state" (FAWC, 2011). Indeed taking care of the animal's welfare can be seen as the most crucial aspect when designing, developing and testing ACI technology. Once again designing tools for animal users makes it more difficult to assess the factors affecting the well-being of both test subjects and possible future users. The Medical Research Council (MRC, 2005, p. 2) states it is only possible to conduct medical research on human participants if the researches have "obtained voluntary informed consent from the participant to participate in research".

Such consent, however, cannot be obtained from animals. Asking for the impressions or experiences directly from the animal being impossible, it is needed to "use other types of assessments and measurements of [the animal's] reactions, emotions and possible behavioural changes in short and long term to be able to see effects on welfare" (Väätäjä & Pesonen, 2012, p. 4). Paldanius et al. (2011) also note that animal rights should be taken into consideration when developing technology, ensuring that it does not cause the animals stress or suffering but instead allows them to behave in a natural way.

Tan et al. (2007, pp. 35-36) present "five design dimensions for human-animal interaction systems". One of the dimensions is defining the degree of interactivity of the system, but the rest four highly focus on the animal's well-being. They point out the area used for interaction "should be safe, comfortable and suitable for the animal". Also ease of use needs to be taken into consideration, allowing the animal to interact with the system in a way natural to it. The animals should be given the choice to take part in the interaction. Finally, the animal should be presented with some kind of gratification for using the system – otherwise "it would be just a case of making the animal perform certain tasks for the entertainment of the human". Ideally a system built for animal-computer interaction would perform highly within all of these five areas.

The Farm Animal Welfare Committee (FAWC, 2011) also presents "ideal states" for animals' welfare in the form of Five Freedoms: the freedom from hunger and thirst, the freedom from discomfort, the freedom from pain, injury or disease, the freedom to express normal behaviour and the freedom from fear and distress. The idea behind these can very well be implemented to also cover animals' conditions while interacting with proposed computer technology, especially since, as Väätäjä and Pesonen (2012, p. 2) suggest, neglecting just one of these freedoms "increases stress and leads in long-term to lowered welfare (distress) of the animal".

TABLE 1 Examples of differences between humans and animals when evaluating ethical implementation of technology for these user groups

User group	Humans	Animals
Can suffer from stress and discomfort	yes	yes
Can voice opinions and experiences	yes	no
Can give clear consent to participate	yes	no
Can voice what she/it needs or wants	yes	no

Some examples of evaluating the animals' experiences can be found in studies with both wearables and other technological solutions. Lee et al. (2006) found that when presented with a choice to wear or not to wear the vibrating jacket the chicken chose to enter through the door that lead to it getting on the jacket and testing it 73% of the test time. Even with added weight to the door leading to the jacket the chicken still chose it 70% of the time. This lead the researchers to safely state the chicken both positively chose the door leading to it wearing the jacket and found the resulting experience pleasurable. According to Tan et al. (2007) studies on Metazoa Ludens (Tan et al., 2006) showed the hamsters playing the game presented positive signs of them playing at their own free will. During the test time the number of times per day hamsters chose to play the game increased, even after adding a minor obstacle to make it more difficult to initiate game play. On a separate study the hamsters' health was reported getting better after six weeks of playing the game, showing a proposed 'gratification' feature in the form of increased physical well-being. This follows the group's intention to emphasise the system's significance to both benefit the animal itself as well as the human-animal interaction by way of positive motivation for both engaged parties.

According to Lee et al. (2006) Duncan (1996) has stated that when considering animal welfare the important thing is not to know exactly what the animal is feeling – just whether it feels good or bad. Evaluating even this can still be a difficult task, especially when done by non-professionals such as pet owners: In the study conducted by Lee et al. (2006) 48% of the people interviewed did not like the idea of a jacket with electronic devices being worn by their pets. Still 68% of the same group believed their pet would enjoy the sensation delivered by the jacket. Such paradoxical results may also follow from simply trying to evaluate such a new type of a system.

Another ethical question besides evaluating the animals' welfare while using ACI technology lies in the reasoning to implement such technology in the first place. As mentioned earlier, many researchers seem to be worried of the well-being of pet animals and hope to bring humans new ways to interact with their pets through computerised interaction. Still, most of the proposed technology seems to be directed more towards filling the needs of the pet owners than the pets themselves. Tan et al. (2007, p. 30) point out how it is "important to note that owners spend many hours at work or on business trips, away from home and their pets". Ping, Farbiz and Cheok (2004, p. 509) also state that "in our modern lives, we need a mechanism to feel the presence and entertainment with our pets, no matter where we are, on work or business". Accordingly

Paldanius et al. (2011, 2649) note that in their studies it became clear pet owners indeed “seek relief for their consciences”, when for example leaving a pet home alone while spending a full day at work. They point out the importance of maintaining focus while developing this kind of products or services: it is essential to recognise whether the emphasis should be on animal or human users.

McGrath (2009, 2531) notes that to really evaluate user satisfaction with this kind of systems “benefits for all the parties” should be taken into consideration, but the real beneficiaries of providing such high technology systems to our co-species are sometimes hard to determine. Also Väätäjä and Pesonen (2012) question the intentions behind developing for example games for dogs, pointing out they may indeed be built mainly on the needs of humans, without really understanding the needs of the animal or making its life any better. Concerning Hello-Fish Jang and Lee (2004, pp. 559, 563) mention how, when away from home, it is not possible for humans to watch and feed our pet fish “so that we feel pleasure by their presence” and express how the system “explores how to obtain the same feeling and mood that we experience with our live pets and fishes even in a remote place” *[sic]*. This makes one wonder, what is in it for the fish? Is it fair for humans to use pets this way to try to increase their own happiness? Is this the way to relief one’s conscience regarding neglected pets alone at home? Schweller (2012) suggests that if the apes, already very capable touchscreen computer users, could use the devices to communicate with their handlers, they could, for example, ask changes to be made to their habitat and living conditions making them even better suited to fit their needs. Such clear objects, strongly focusing on making the animal and its needs the number one priority, could help make it easier to clearly see the true beneficiaries and driving forces behind these interaction enterprises.

4 CONCLUSIONS

Animal-computer interaction can be seen as a way to include animals into the modern ways of computerised interaction already natural to humans. As an area of study it can still be seen being in its infancy and therefore the ideas and proposed implementations studied range widely not only in scale and practicality but sometimes also in seriousness. In the beginning of this thesis three research questions were laid out, to help define the characteristics differentiating animal-computer interaction from human-computer interaction. The first question asked was "What are the possible implementations of ACI technology?"

It could be said the possibilities of implementing ACI technology are, at this point, almost endless – both in our homes as well as outside of it. The current research being fairly theoretical in nature, instead of stemming from a specific need, even the wildest ideas are feasible and worth studying. In practice, though, ACI technology could be used by very different animals ranging from tiny pet hamsters to farm animals and even species considered more 'wild', such as apes and dolphins. Presented applications range from simple fun and games for the animal to share with human friends to implementations helping increase the animals' quality of life by for example letting them to enjoy physical touch in an otherwise restricted environment or communicate their needs to humans.

In some cases the true interactivity of the presented computerised systems can be argued, at least from the animal's viewpoint: sometimes it is the human pet owner doing the 'heavy lifting" while the animal needs only to follow the owner's cues, while in some cases the interactive tools turn out to be mere monitoring devices leaving it unclear what is the animals part in such 'interaction'. Compared to human-computer interaction there is still much to improve within the field of animal-computer interaction to fully entitle its name.

Another research question posed was "What type of challenges lie in expanding the use of computer-mediated interaction from humans to animals?" In an ideal world all computer systems for animals would be designed in a way understandable to them, just as is the case with systems for human use. They should allow the animals to act in a way natural to them while bringing more value to their lives without any drawbacks – the animals' welfare, both mental and physical, should always come first. In reality such implementations are difficult to build with many challenges hindering the process: With non-human users the usability of these systems is hard to evaluate, as are the ethical aspects of designing tools for animal users unable to clearly protest their involvement. Unlike with human users, it is not possible to ask animals what kind of technological improvements they would like to see in their lives.

Though some examples of real benefit for the well-being of for example farm animals have been proposed, actual use and benefit gained by the animal can still often be debatable. Indeed, the final research question asked was "Who would benefit from the implementation of animal-computer interaction?" This often still remains somewhat unclear no matter the noble intentions of the researchers to improve the animals' quality of life. Not only are the need and usability aspects hard to determine so are also the animals' perceptions of improvement and benefits brought by proposed ACI implementations. Tools are not only developed based on human understanding of an animal's needs and wishes but in many cases also to fulfil the human's wishes of increased interaction with the animal.

Another interesting question remaining is how the animals interacting with computers – and us humans through them – actually understand this interaction? Is it needed for them to be aware they are in fact communicating through a computer instead of playing with just another toy and is it even possible for animals to do so? Cats playing with remotely operated cat condos and hamsters chasing physical objects most likely cannot recognise the involvement of their human owners on the other end of the interface. Is it acceptable the pleasant feeling of stroking or some other sensation conducted by a wearable vest simply comes from 'somewhere', as long as it is pleasing from the viewpoint of the animal? Surely such actions could be automated making again the interaction involved redundant and less efficient.

Past studies have often claimed to stem from the interest to make the animals' lives better, but eventually it has been the human conscience reaping the benefits of feeling relieved after finding such new ways to stay in touch with the animal. In the future it would be interesting to see studies focusing more on the true benefits of computerised interaction from the animals' point of view, trying to find out what there really could be in it for them in development of ACI technology. This combined with serious approach towards animals as future computer users could truly make ACI development something to help us humans to connect with and understand the rest of the species on this planet better, as the possibilities in the field are vast but still largely unknown.

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