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# Envisioning Future Playful Interactive Environments for Animals

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**Abstract** Play stands as one of the most natural and inherent behavior among the majority of living species, specifically humans and animals. Human play has evolved significantly over the years, and so have done the artifacts which allow us to play: from children playing tag games without any tools other than their bodies, to modern videogames using haptic and wearable devices to augment the playful experience. However, this ludic revolution has not been the same for the humans' closest companions, our pets. Recently, a new discipline inside the Human Computer Interaction (HCI) community, called Animal Computer Interaction (ACI), has focused its attention on improving animals' welfare using technology. Several works in the ACI field rely on playful interfaces to mediate this digital communication between animals and humans. Until now, the development of these interfaces only comprises a single goal or activity, and its adaptation to the animals' needs requires the developers' intervention. This work analyzes the existing approaches, proposing a more generic and autonomous system aimed at addressing several aspects of animal welfare at a time: Intelligent Playful Environments for Animals. The great potential of these systems is discussed, explaining how incorporating intelligent capabilities within playful environments could allow learning from the animals' behavior and automatically adapt the game to the animals' needs and preferences. The engaging playful activities created with these systems could serve different purposes and eventually improve animals' quality of life.

**Keywords** Animal Computer Interaction, Games, Playful, Interaction Design, Ambient Intelligence

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# 1 Introduction

The world's diversity of species is one of its most impressive characteristics. There are approximately 1.1 million of known animal species in the world[1], each of them contributing and giving shape to the ecosystems we live in. However, as a consequence of this vast heterogeneity of animal beings, having a common way of communication between all of them becomes impossible. Even within the *Homo sapiens* species, some handicaps arise when humans with different cultures and/or languages try to communicate. Nevertheless, there exists one behavior present in the majority of animal kinds which seems to remove the communicative barriers among species, facilitating the interaction and creating strong bonds between participants: play.

Play is one of the most natural and inherent behaviors among animals[2]. In Huizinga's own words (Huizinga 1985):

> "Play is older than culture, for culture, however inadequately defined, always presupposes human society, and animals have not waited for man to teach them their playing."

As Huizinga points out, animals do not need to be taught to play with each other or with humans. For them it stands as a natural activity which may have several purposes that are not yet completely understood (Bateson and Martin 2013). In fact, one of the main aspects of play is that it is fun and this is the main source of motivation for all sorts of animals, including humans.

This aspect, being fun, has motivated humans not only to play but to design artifacts that make the play activity even more attractive. The nature of human play has therefore evolved with technological innovations from primitive stone skipping to modern interactive electronic games. However, in this hominid evolution giving rise to what Huizinga called the *homo ludens* and some call today *homo ludens electronicus*, other species have been left behind. This is the case of animals, as animal play has not experienced yet this digital ludic revolution in the same way as human play has.

This chapter firstly describes the factors which led to the emergence of a new technological trend focused on animals as the target users of digital systems, explaining how animal play could be of great importance in this new research field. Secondly, a review of existing work on technology-mediated interaction with animals is presented, with a specific discussion of previous playful digital games for animals. Based on this review, we propose a new and more flexible way of understanding animal playfulness with digital systems: intelligent playful environments for animals. A conceptual development framework for these systems is defined, presenting an analysis of existing playful games for animals under this framework. This analysis will help to detect lacks and needs in terms of digital playful inter-

[1] http://www.catalogueoflife.org/annual-checklist/2014/

[2] For now on in this chapter, when referring to animal beings we are not including humans in this group, although the *Homo sapiens* species is included in the animal kingdom.

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faces for animals. Finally, application scenarios, emerging issues and opportunities for interdisciplinary research are described for further exploration.

## *1.1 Animals as Target Users of Digital Systems*

Since the emergence of Human Computer Interaction (HCI) as a discipline, the benefits that HCI applications and studies have brought to human well-being are countless. Understanding how humans interact with digital systems has allowed researchers and developers to design and build innovative and more natural interfaces, improving the user experience and lowering the gap between the virtual and the real world. More specifically, the contribution of HCI studies to the evolution of human play has been of extreme importance. HCI studies have allowed us to build digital devices which enhance our playful experiences, by making them more immersive and realistic: high performance portable video consoles, joysticks, motion sensing devices, technology for augmented reality scenarios, etc.

In the last years, we have seen how electronic devices meant for humans have been tuned or adapted for animals to play with them. Sometimes, even animals by themselves get interested in the devices around them and start using our digital gadgets in a way we would never have imagined. In Fig. 1, a dog plays with an electronic ball, called *Sphero*[3]. This commercial device is controlled by a human, who uses a smartphone or tablet application to make the ball move while emitting light. Both the movement and lighting factors cause the animal to really get involved in a playful activity chasing and touching the electronic ball. Figure 2 shows two orangutans in a zoo using an iPad application as part of the *Apps with Apes*[4] initiative. *Apps with Apes* aims to provide stimulating activities for orangutans in zoos by allowing them to play with several iPad applications. There are applications for painting, playing the piano, exploring pictures, etc. A volunteer approaches the iPad to the orangutans' cage and holds it as long as the orangutan wants to play.

[3] http://www.gosphero.com

[4] http://redapes.org/multimedia/apps-for-apes/

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**Fig. 1.** Dog playing with a *Sphero*

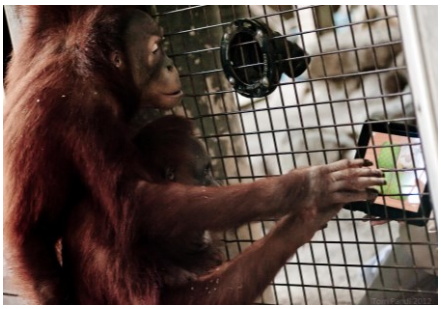

**Fig. 2.** Orangutans playing with an iPad as part of the *Apes with Apps* initiative

Animals' interaction with our digital world is sparking our interest, as we begin to wonder whether they would be able to play with our human-centered electronic devices. However, little research has been done for developing digital systems specifically designed for animals in comparison with the efforts that have been focused on the construction of human-computer interfaces.

Recently, an emergent discipline inside the HCI community called Animal Computer Interaction (ACI) (Mancini 2011; Mancini 2013) has started to shape. ACI principles are based on recognizing animals as target users of digital systems and developing computing technology specifically designed for them by studying how they interact with digital interfaces. Understanding animals' behavior with computer-mediated systems will help to develop systems more suitable for them, eventually improving both humans and non-humans quality of life. The ACI community is aware of the ethical issues derived from conducting studies with animals, and some guidelines have been proposed in order to ensure animals' welfare at all possible means (Väätäjä and Pesonen 2013).

However, ACI studies with animals have to face an important obstacle. If animals are going to be the target users of the systems, they have to be included in the design and development process, in the same way HCI includes human stakeholders in the construction of new interfaces. Generally, usability studies with humans rely on verbal or written communication for both giving instructions to the users on how to use the system, and for gathering information and feedback from the users about the system being evaluated. The impossibility of verbal or written communication with animals forces ACI researchers to look for other evaluation methodologies that allow them to communicate and understand the animals' interaction with the digital system. In addition, a psychological perspective is required in future ACI studies. The inability to verbally communicate with a group of interest can lead to erroneous conclusions when conducting studies based on choices (Ritvo and Allison 2014). If a subject is presented with two options, her choice could be based on the most desired option (which would be our assumption) or on the least aversive one (which does not mean it is a good option). Careful assessment should be performed in this kind of studies.

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When looking for effective ways to understand how animals interact with computer-mediated systems, ACI applications should rely on their most natural and intrinsic behavior: play. The ACI community should take advantage of the animals' natural disposition towards playing and set playfulness as the basis of any system targeted at them. The use of technology-mediated playful experiences within the ACI field will provide engaging ways of conducting usability studies with animals, as well as an effective and worldwide understood way of communication between species - play. Moreover, advances in the ACI field will lead to the improvement of the digital devices used in playful experiences. These digital devices will become more and more suitable for animals as ACI insights are applied on their development process. As a consequence, a symbiotic relationship between ACI and animal playing will be created, giving rise to the era of the *animal ludens*.

## *1.2 Playful Environments as Intelligent Ecosystems*

Several works have already addressed the design of playful experiences for humans (Nijholt 2014), even analyzing the effects play has on human pleasure. According to (Csikszentmihalyi 1975; Costello and Edmonds 2007), the pleasures of play should be studied by considering multiple categories related to Creation, Exploration, Discovery, Difficulty, Competition, Danger, Captivation, Sensation, Sympathy, Simulation, Fantasy, Camaraderie and Subversion. However, these constituent elements of playful experiences that apply to humans may not be applicable to other species. They may need to be adapted for different types of animals or even be tailored for specific individuals or situational contexts in a transparent way.

Context-awareness, adaptation and transparency are the main building blocks of a currently growing technological approach known as Ambient Intelligence (AmI) (Weiser 1991; Norman 1998). The AmI research community seeks for the disappearance of computers as we already know them, providing users with seamless systems comprised of plenty of interconnected digital devices (ubiquitous computing). The communication between all these devices should be invisible to the user (transparency), and the system's main goal will be providing the users what they need taking into account their contextual situation (context-awareness). The infinite range of possible contexts and user preferences prevent developers from building a specific system for each situation. Instead, the solution lies on applying some sort of *intelligence* in a way that environments can learn from people's behavior and automatically adapt themselves to the context, even anticipat-

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ing people's needs. For this purpose, diverse computing areas merge their efforts to come up with a fully integrated intelligent environment: artificial intelligence for activity recognition and decision making, sensing devices for monitoring users and environmental status, HCI advances to provide easy-to-use and useful interfaces, etc. As a result, AmI advances are helping to improve human well-being without any doubt.

There are certain parallels between humans' need for intelligent systems and animals' playful revolution. Playful experiences for animals will be diverse and should be tailored to their specific characteristics and needs. Thus, developing a specific playful system for each contextual situation will not be feasible due to the extensive range of possible scenarios. Playful environments could be provided with the same kind of *intelligence* that AmI proposes for human environments. Therefore, playful environments will have multiple digital playing elements, which could communicate between them in a transparent way for both humans and animals. These environments, which we call *Intelligent Playful Environments for Animals (IPE4A),* would extract knowledge about the animals inhabiting them, learning from their behavior and preferences. The environment could rely on this information to evolve and auto-adapt to the situation, creating suitable playful activities for each context without having to develop a specific system for each purpose/situation.

The next section will review existing works on animals' interaction with computer systems. This review will provide the reader with the adequate background to better understand the purpose of Intelligent Playful Environments for Animals.

## 2 Related Works

Despite ACI being a recent research field, studies concerning animals, their cognitive capabilities and the way they understand their surroundings have existed for a long time (Rumbaugh 1977; Matsuzawa 2003; Mancini et al. 2012). This section will analyze how computer mediated interaction with animals has evolved over the years, giving a closer overview on the recently emergence of technological playful interfaces for animals.

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## *2.1 Computer Interfaces for Animals*

In the 1970s, the *LANA Project* was one of the first attempts where computer-based interfaces were used to study the linguistic capabilities of chimpanzees (Rumbaugh et al. 1973; Rumbaugh 1977). The system consisted of a keyboard with *lexigrams*, i.e. abstract symbols representing nouns, verbs, activities, etc. These lexigrams allowed the construction of sentences in an English-like language called *Yerkish*. Lana, in Fig. 3, was the first chimpanzee who learnt how to use the lexigram keyboard to communicate with humans. Touch screen computers and iconic keyboards have also been used in later projects with chimpanzees, such as the *Ai Project* (Matsuzawa 2003), named after the female chimpanzee who pioneered the study. This project aimed to deepen into the cognitive capabilities of chimpanzees, and results suggested that they are able to outperform humans regarding simple memory tasks. Due to the DNA similarities between chimpanzees and humans, the interaction methods used in these systems were similar to the ones conceived for humans.

**Fig. 3.** Chimpanzee Lana using the lexigram keyboard to request food (Image courtesy of. Dr. Duane Rumbaugh)

Communication between dolphins and humans has been another area of interest. The *SpeakDolphin*[5] project uses a *Panasonic Toughbook* to introduce dolphins

[5] http://www.speakdolphin.com

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to the use of touch screens. Using this interaction modality, dolphins have to perform cognitive associations between real objects and pictures on the screen, selecting on the touch screen the picture of the object they are shown in real life. The next step would be adding symbols associated with actions in order to create a useful language interface.

One of the firsts attempts to apply HCI methodologies and User Centered Design for building computer interfaces for animals is *Rover@Home* (Resner 2001). This work grounds on the idea that the communication between humans and dogs is asymmetric. Therefore, the interfaces for dogs have to differ from the interfaces for humans in order to adapt to the communicative subject in each case. A computer-based system for clicker-training with dogs is presented, allowing humans to remotely train their dogs.

Wearable technology has also been used for improving remote communication between pets and their owners. This is the case of *Poultry.Internet* (Teh et al. 2006; Lee et al. 2006), which proposes a tangible interface for poultry and humans at different locations. The chicken wears a special jacket (see Fig. 4) which emulates human touching when the human touches a pet doll. Also, the movements of the chicken are monitored and notified to the human using a haptic device that the human wears on his toes. In addition, computer-mediated tactile interaction with dogs has been studied, claiming that this interaction modality could help to alleviate dogs' stress and anxiety (Väätäjä 2014). For the purpose of this study, dogs' behavioral problems and possible causes of stress have been analyzed. The main goal of this work is to provide a useful framework for improving the development of future wearable devices for dogs which emulate human touch.

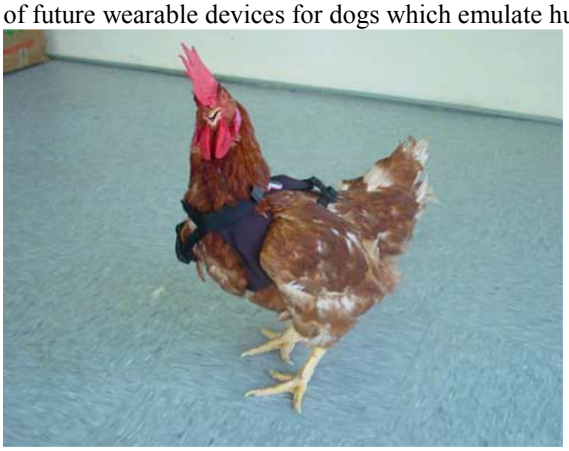

**Fig. 4.** Chicken wearing a jacket which simulates human touching sensation (Image courtesy of Dr. Adrian David Cheok)

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Some studies have reported how traditional human-animal interaction is affected by the use of technology, in this case, a positioning system for hunting dogs (Paldanius et al. 2011; Weilenmann and Juhlin 2011). This system allows hunters to follow in real-time the position of their hunting dogs. This additional information enriches the perspective the hunters have about the dogs' behavior. As a consequence of knowing where the dog is, hunters begin to imagine what the dog will be doing based on its movements. The relationship between the dog and the human changes, as the hunter gives instructions to the dog based on the location information he is receiving. However, the study points out the need for user-centered design when building technology for human-animal interaction and it also advocates for ensuring animal welfare in the design process.

ACI principles have also been used to improve the task carried out by Diabetes Alert Dogs (DAD) (Robinson et al. 2014). A DAD is a dog trained to detect changes in blood sugar levels in real-time. These dogs are paired with a human suffering from diabetes, and alert the human when their sugar levels decrease rapidly. However, if the human falls into a coma due to a hypoglycemic attack, the dog is unable to help him. This work proposes several dog-oriented interfaces which could allow the dog to alert emergency services if a critical situation arises (see Fig. 5). The task of cancer detection dogs can also be improved by using animal-centered interfaces such as the one described in (Mancini et al. 2015). Dogs can be trained to recognize several odors from cancer cells using biological samples from the patient. When the dogs find a positive sample, they report it to their trainers by performing a specific signal convention. However, sometimes a dog's reaction to a sample is uncertain or spontaneous, and the dogs have no method to indicate the degree of certainty on ambiguous samples. This project proposes a canine-centered interface which allows the dogs to sniff normally on a plate placed over the sample, as they usually do. Using a pressure sensor, the system captures and records the pressure the dog puts on the plate containing the sample (see Fig. 6). Each kind of sample causes the dog to sniff with a specific pattern, i.e. the time spent sniffing the sample and the pressure applied on the plate. As a result, the pressure pattern extracted from the sensor allowed more natural and reliable responses from the dogs. Both the project of Diabetes Alert Dogs and cancer detection dogs demonstrate how animal-centered interfaces can not only improve animals' interaction and wellbeing, but also save human lives by enhancing interspecies communication.

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**Fig. 5.** Diabetes Alert Dog using a prototype of the alert device used to communicate with emergency services (Image courtesy of Dr. Clara Mancini and Charlotte Robinson)

**Fig. 6.** Dog using the cancer detection interface (Image courtesy of Dr. Clara Mancini)

## *2.2 Playful Experiences within Animal Computer Interaction*

The motivational factors which bring animals to play have been the focus of several dissertations (Bekoff and Allen 1997; Burghardt 2006). Although there is no universal answer to the reason why animals play, several works within the ACI research field believe that playful-based interactions with animals should bring better results in terms of engagement, communication and user satisfaction (Hirskyj-Douglas and Read 2014; Pons et al. 2014).

There have been several studies where play is used as the fundamental tool to stimulate animals to participate in the activity and interact with the system voluntarily. The main goal of these studies is to improve animals' welfare by addressing different issues that can affect the animals' quality of live: sedentary lifestyle, anxiety/stress, routine and boring training exercises, etc.

Several studies have attempted to motivate physical activity among pets using playful devices which cause the animal to move and perform some physical exercise. *Feline Fun Park*[6] is one of the tangible playful interfaces which promotes pet activity. It consists of three sensors which monitor the pet's activity level. Depending on the activity level of the cat, the system has three mechanisms to motivate the animal to play at different levels of intensity: two mouse toys and tracer lights. The pet owner is also notified about the cat's activity and he can activate remotely the different mechanisms of the system to encourage playing. However, the playful mechanisms provided are

[6] Feline Fun Park: https://www.youtube.com/watch?v=HB5LsSYkhCc

not changing with time, possibly causing that the cat loses interest and stops playing, even if the system continues triggering actions.

*Pawsabilities* (Mankoff et al. 2005) presents a HUI (Human User Interface) and a DUI (Dog User Interface) to reduce canine pets boredom when their owners are not at home. When the system detects that the dog is becoming bored (e.g. by lying on its bed), the HUI notifies the owners remotely so they can activate a mechanism to throw a ball for the dog to play with. On the other hand, whenever social activity is detected on the human side of the system, the DUI activates the video streaming, showing the owners' activity to entertain the dog. This system has not yet been evaluated with enough dogs in order to extract solid conclusions about its benefits to the canines.

*LonelyDog@Home* (Hu et al. 2007) is a web based interface allowing humans to interact with their dogs whenever they are away from home. Through a web interface, humans can have a look at their pets, feed them and engage into remote playful activities with them. This work mostly focuses on reducing owner's worries about their pets' wellbeing when they are left alone at home. Pet owners can connect to the system located at their home using any web browser and communicate with their pets using an action oriented interface such as the one shown in Fig. 7. On the dog's side there is a ball thrower and an electronic feeder connected to the system, speakers and a webcam. Pet owners can issue pre-recorded audio commands, throw a ball, give the dog a treat or feed him. Although some efforts have been done on the animal´s interface in order to provide suitable mechanisms for the dog to interact with the system, there are still some issues regarding the suitability of verbal interactions and visual communication. Dogs' hearing frequencies are different and more acute than ours, thus excellent quality of the audio system is required. Regarding visual communication, *LonelyDog@Home* allows pet owners to see their dogs, but dogs are not provided with a way of communicating with their owners. Therefore, benefits on animal welfare and anxiety reduction should be further studied for this system.


**Fig. 7.** LonelyDog@Home graphical interface for pet owners (Image courtesy of LonelyDog@Home's authors)

Other works such as *Canine Amusement and Training* (Wingrave et al. 2010) use play as a mechanism to help both the human and the dog to spend more time together while introducing dogs into training. It offers several kinds of games focused on calm-

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ness, obedience and joy. In each game, lights and figures are projected on the ground, and the human is required to give appropriate commands to the dog, which vary in line with the goal of the game, e.g. obedience games require the dog to remain quiet next to the human. In this way, the dog learns how to obey commands in a way that is amusing for both participants. This work allows the human to spend more time with his dog, strengthening their relationship, while providing guidance in a complex task such as dog training. The game has been designed with the assistance of a canine trainer, and the sensing infrastructure has been prototyped with dogs of different sizes.

There are some other systems designed just for the fun of playing and competing. *Cat Cat Revolution* (Noz and An 2011) is a digital game for iPad which shows an animated mouse moving across the screen. Early prototypes of the game allowed to test several combinations of brightness, size, color and movement of the digital mouse in order to accommodate the interface to cat's visual characteristics. The iPad application combines graphical hints and sounds to incite the cat to capture the mouse. There are two playing modes: the digital mouse is moved randomly across the display, or is controlled by a human. In the latter case, the human user connects its iPhone to the iPad application, and the screen on the iPad is replicated on the phone. In this way, the human can control the mouse's orientation and velocity by using his fingers. Observational findings derived from a study with 7 couples of cats and their owners showed that the humans considered the game as fun and useful to reinforce their relationships, as well as to create new forms of communication with the animal.

*Metazoa Ludens* (Cheok et al. 2011) proposes a mixed reality game where a human and a hamster can play together. The playful interface for the hamster is a physical moldable surface which adapts its shape using mechanical actuators. The hamster can enter and exit the playground freely. The human interface consists of a virtual 3D game where two avatars are represented, one for the user and another one for the hamster. The human can move its own avatar through the virtual terrain, and these movements are transferred to a physical bait in the hamster's playground. The real movements of the hamster are also captured and imitated by the hamster's avatar in the digital game. Therefore, a chase between the hamster and the human occurs both in the digital and in the real world simultaneously.

The *Playing with Pigs* project (Alfrink et al. 2012) is an innovative interspecies game designed to strengthen relations between humans and pigs as companions. The pigs are situated in front of a large touch sensitive display showing a light ball controlled by a human player through an iPad application. The iPad application shows the virtual replica of the light ball and the pigs' snouts when they approach the ball. The user has to keep the pigs in contact with the ball and lead them through a triangular target on the screen to score points. However, although this game may be interesting for humans, as they have a scoring scale and goals to meet, it is questionable how much time will pigs pay attention to the game or how could this benefit pigs if they are not aware of the human who is playing with them.

*Felino* (Westerlaken et al. 2014; Westerlaken and Gualeni 2014) is an interspecies video game designed using ACI principles. The design and development of the game is informed with the animals' experiences and observational feedback gathered from

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cats' human companions and annotated video recorded sessions. The game allows a human and a cat to play together on a shared tablet screen (see Fig. 8). Cats can catch fish and other sea creatures which appear and move across the screen, while humans can control several options of the game, like the size, speed and movements of the creatures. Moreover, every time the cat catches a fish, a sphere is released. Those spheres can be caught by a crab avatar which is always on the screen. The crab is controlled by the human player, and by collecting spheres, new crabs appear following the older ones. Cats can also interact with the trail of crabs the human creates. Therefore, human and cat can cooperate in a shared digital world, and the human can adapt the game to the cat's reactions and preferences.

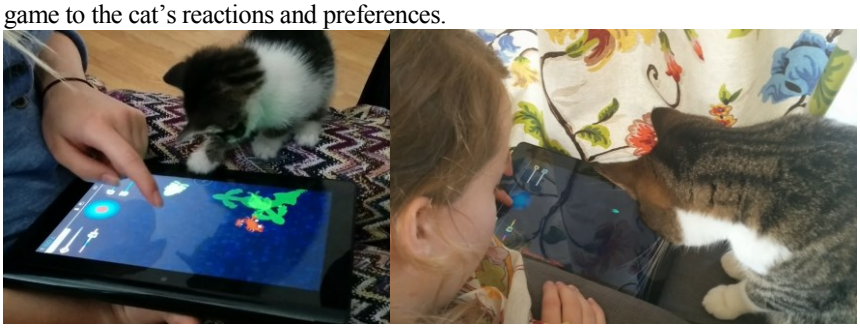

**Fig. 8.** Cats playing with *Felino* (Images courtesy of Michelle Westerlaken)

Although all these projects are based on playful activities, each one has been specifically designed for its own purpose. Moreover, these systems do not adapt automatically to changes and in most cases the activity has to be started off by a human. If the ACI community wants to take a step forward in developing natural systems for animals, intelligence, automation and reactivity have to be present in playful environments in the future. In the same way as Ambient Intelligent systems adapt themselves to their inhabitants, by recognizing and anticipating their needs, intelligent playful environments for animals must learn animals' behavior and preferences in order to be able to react properly. A playful environment with these features could automatically create and adapt play activities to engage the animals in physical exercise, raise their mood or train them while having fun. The next section will give a definition for future intelligent playful environments for animals and the features these systems should include.

## 3 Situating Intelligent Playful Environments

This work sets the foundation for intelligent playful environments for animals starting with a definition of what they are:

*An intelligent playful environment for animals, or IPE4A, is an animal-centered ecosystem with intelligent capabilities which is able to learn from the an-*

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*imals' behaviors and interactions, using the acquired knowledge to adapt itself to the context, creating engaging playful activities which do not necessarily need human mediation to evolve.*

In order to provide a conceptual taxonomic framework for the future construction of these environments, their requirements are listed as follows:

- *Playfulness*. The environment has to consider play as the conductive engine of any activity it creates.
- *Intelligence*. The environment must be able to capture and analyze the occupants' interactions and behaviors, extracting patterns and preferences. This knowledge will be useful for the creation and evolution of playful activities, whose purpose and dynamics will be adapted to the context.
- *Reactivity and interaction*. The system must react suitably to the animals' interactions, and also provide proactive stimuli to the animals to foster communications between the system and the users (both human and non-human).
- *Animal-centered design*. Every intelligent playful environment must be designed and developed specifically for animals, with appropriate devices and interaction methods and prioritizing the animals' comfort, safety and well-being.

There are also several features that can vary from one playful scenario to another and should be considered in the design of future IPE4As:

- *Number of participants (single-player, n-player & multiplayer)*. The playful environment can be designed for one participant (single-player), a fixed number (n-player) or it can respond to any of the participants that walk into the ecosystem (multiplayer). If more than one participant is considered, the design of the environment should include ways to handle abandoning scenarios, i.e. when one or more players leave the game or physically come out of the ecosystem.
- *Species of the participants (one species vs. multiple species)*. Animals probably do not perceive their environment in the same way humans do (McGrath 2009). Moreover, different animal species may not have the same conceptual view of the world. As a consequence, animals from distinct species will not behave similarly given the same scenario. This affects several design decisions in the construction of interfaces and interactive systems targeted at animals: from the way in which they will be encouraged to play to the reference health values the system will use to create a physical activity. Consequently, the intelligent playful environment can be designed specifically for a single animal species or it can be designed to recognize the animal's species and adapt itself to it.
- *Human participation (participant vs. non-participant)*. Humans may or may not take part in the playful activity. In the former case, the system will only react to animal interaction. In the latter case, it will respond to both human and non-human actions.
- *Human presence (physical vs. virtual)*. If humans take part in the playful experience they can either be physically present in the environment or participate remotely. The remote participation may encompass a wide range of scenarios:

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from pet owners in their spare time at work, to child patients in hospitals seeking amusement and distraction.

- *Control*. The intelligent features and reasoning engine of the playful environment can learn and take decisions autonomously, i.e. without human intervention, or they can be guided by explicit human knowledge. The latter idea implies that IPE4As can provide mechanisms to allow human users to define explicit behavioral patterns the system must follow. For example, if a zoo worker wants the activity to be paused every day at midday to feed the animals and resumed after all the animals have finished, she should be able to easily program the system with such desired behavior.
- *Information acquisition*. The system inputs can be gathered by different technologies: wearable devices, sensing (motion sensors, pressure sensors, etc.), video and audio recordings, etc. In all cases, the selected capturing devices should be non-obtrusive and ensure the animals' safety and comfort.
- *Learning inputs*. Both humans and animals can coexist within the playful environment, interacting with the system and with each other. The design phase of the environment has to establish which of these interactions will serve as learning inputs for the intelligent system. It also has to be decided if only animal interactions will be included or if human inputs will also be considered. In some cases, human interactions with their pets could provide very valuable information to the learning system. As an example, pets are not able to verbally communicate when they are bored, but their owners can recognize their mood and start playing with them. The system could therefore learn which activity raises the pet's mood by looking at the owners interactions with the animal.
- *Sense-guided stimuli*. Since distinct species may behave differently in the same context, their preferences and motivations may also differ. Some species might therefore feel more attracted by visual stimuli such as lights or mobile mechanisms (e.g. cats), while others would respond more eagerly to olfactory clues (e.g. dogs). In order to use the proper actuators and devices to capture the animal's attention, IPE4As should rely on the most suitable stimuli for each animal species in a given context.
- *Single-purpose vs. multi-purpose activities*. Playful activities created by the environment can be focused on solving just one issue of animal well-being, e.g. a game which only fosters physical activity. On the other hand, more complete activities covering several issues can also be created, e.g. a game which includes a training element at the same time as physical activity is being monitored and fostered by the system.

**Table 1.** List of requirements and features of intelligent playful environments

| Requirements | Features |
|---|---|
| Playfulness | Number of participants |
| Intelligence | Species of the participants |

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| | |
|---|---|
| Reactivity and interaction | Human participation |
| Animal-centered design | Human presence |
| | Control |
| | Information acquisition |
| | Learning inputs |
| | Sense-guided stimuli |
| | Single-purpose vs. multi-purpose activities |

## 4 Situating Current Playful Environments for Animals

The design and development of future intelligent playful environments comprises many factors that should be analyzed and informed by the existing digital games involving animals. Table 2 shows a classification of the existing digital playful experiences for animals described in Sect. 2 in terms of the game features outlined in Sect. 3. The next subsections will open the discussion about where should intelligent playful environments put their efforts to improve current lacks in playful scenarios, and how could ACI research inform the design of future intelligent systems for animals.

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**Table 2.** Analysis of existing playful games for animals under the proposed framework

| Work | Number of participants | Species of the participants | Human participation | Human presence | Control | Information acquisition | Learning inputs | Sense-guided stimuli | Purpose |
|---|---|---|---|---|---|---|---|---|---|
| Pawsabilities | Two | Dog<br>Human | Yes | No | Human<br>System | Camera<br>Pressure sensors | N/A | Visual (movement) | Avoid boredom |
| LonelyDog @Home | Two | Dog<br>Human | Yes | No | Human | Dog: Camera<br>Human: Web-based interface | N/A | Audition | Avoid loneliness |
| Canine Amusement and Training | Two | Dog<br>Human | Yes | Yes | Human | Sensors on the dog (breathing, position, etc.) | N/A | Visual (colors)<br>Audition | Training<br>Fun |
| CatCatRevolution | Two | Cat<br>Human | Optional | Yes | Human<br>System | Direct touch of the device screen | N/A | Visual (movement)<br>Audition | Fun |
| MetazoaLudens | Two | Hamster<br>Human | Yes | Optional | Human<br>Animal | Hamster: movement detection<br>Human: keyboard and mouse | N/A | Visual (movement) | Fun |
| Pig Chase | Two | Pig<br>Human | Yes | Optional | Human<br>Animal | Pig: Direct touch of the interactive surface<br>Human: Direct touch of the tablet | N/A | Visual (movement, colors) | Fun |
| Feline Fun Park | One | Cat | No | No | Human<br>System | Sensors (weight, light, movement) | N/A | Visual (movement, lights) | Fun, Physical activity |
| Felino | Two | Cat<br>Human | Optional | Yes | Human<br>System | Direct touch of the device screen | N/A | Visual (movement, colors, size) | Fun |

*N/A* Not applicable

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### *4.1 Game Participants: Static or Dynamic Approach?*

Human participation is considered important if we want to strengthen the relationship between humans and other species. Nevertheless, some works have left open the possibility of the human joining the game, allowing the animal to participate alone if the human is not available. This should be an important requirement if the animal is going to spend considerable time alone or separated from the human.

In games requiring human participation, two tendencies have been detected. The philosophy behind games such as *Pawsabilities* and *LonelyDog@Home* only makes sense when the human is distant from the animal, and thus remote communication is the only way of human interaction with the system. Other works such as *MetazoaLudens* or *Pig Chase* can take place either with humans physically present in the same environment or with them remotely interacting with the interface provided. In order to reach a higher degree of flexibility, we propose that intelligent playful environments support both animals playing alone and together with their human companions, the latter case with its two modalities: remote or in-person participation. The environment should adapt the game to the context of the moment, allowing the human entering and exiting the game at any time without causing frustration to the animal. For example, if a human is playing with her dog but suddenly a phone call interferes, the human should be able to answer the phone without causing the game to terminate. The game should be adapted to continue without the human player, and if eventually the human wants to get back into the game, the system should create the appropriate game flow in order to incorporate the human back into the playful activity.

The same argumentation can be applied to animal participants. The feature *number of participants* in Table 2 indicates the number of players the game was originally designed for. As an example, it is understood that several cats could be playing simultaneously to chase a mouse on the screen of *CatCatRevolution*. However, the system does not distinguish between the touch of different cats on the same screen and thus, to the system's knowledge, there is only one cat playing at a time. It can be seen that only games for one or two players have been designed, and two player games always include a human participant. A more dynamic approach should be provided in future intelligent gaming environments, where several animals and/or humans could participate. The participation of an animal/human in the game implies that the system recognizes him as a new and differentiated user from the other participants of the same species. Therefore, both animals and humans should be able to enter and leave the game whenever they need to. Neither the human nor the animal should become deprived for their decisions about participating or not in the game. The game should be adapted to the

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number of current participants, starting when the first participant comes in, and terminating when the last participant abandons the game.

Until now, humans are the agents mediating the interaction between animals and computing interfaces. From the eight games being analyzed, six of them require the human to start the playful activity. Only two of them can autonomously perform some interaction to attract the animals' attention, and both of them monitor the animals' activity level in order to notify the human in case they want to intervene. It is essential for the future development of intelligent playful environments that the system itself could decide to initiate or terminate a playful experience. Firstly, if the system detects some need on the animals and there are no humans around, the environment should be able to start the playful interaction in the same way a human would do when detecting some animal's urge. Secondly, some animals may want to play the whole day, but it might be inadequate because of health and behavioral reasons. The system should be able to end the playful activity when it detects that the purpose of the activity has been met. In this context, there are several questions that need to be previously addressed:

- How can the animal be aware that the system wants to initiate the interaction?
- How can the system involve voluntarily the animal into the playful activity?
- How can the system itself communicate or attract the animal in order to start a playful experience?
- How to end the playful activity without negatively affecting the animal?
- How to make the animal understand that the playful activity has ended?

Another important issue that has not been addressed yet is the possibility of the animals initiating the playful experience. How can we build successful playful experiences for animals if we do not allow the animal to start playing freely at their own will? Several questions arise around these ideas, and further studies within the ACI field should bring new insights on how to provide the best suitable way to let the animals decide when to play:

- How can animals initially learn that the system will respond to their actions by starting a playful experience?
- Which mechanisms/behaviors will animals use to start the interaction with the system? Will they use the same behaviors they use to communicate playful intentions with humans/other animals?
- How can the animal withdraw from the playful experience?
- How can the system recognize that the animal wants to stop playing in order to stop all the interaction?
- Could the system analyze the factors which lead to the end of the activity and use this information to improve the next playful experience, by making it more appealing and time lasting?

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### *4.2 Adapting Computer Interfaces to a Broader Audience: Species Awareness and Interrelationships*

Regarding the species of the animals' participants, it is observed that most of the games have been designed for dogs or cats, while only one game has been developed for small pets such as hamsters. It is remarkable that only one of these games has considered animals outside the pets' domain as active players, which gives an idea of what kind of users ACI research is currently addressing. Perhaps pet companions are the first animals coming to our minds when we think about the animal kingdom, but we shall not forget to address other animal species that may also require playful environments. Wild animals could also benefit from ACI advances: if computer mediated interaction can help us to communicate with wild species by means of play, our knowledge about them will improve significantly. Moreover, semi-wild species such as animals living in zoos could also benefit from playful interactive environments, as it will be described in Sect. 5.

Another issue to be solved is that current digital games for animals only address one animal species at a time. Interspecies relationships between animals, although frequent in natural environments, are not supported by current playful interfaces. An intelligent playful environment for animals should support this variability and foster interspecies relationships, creating suitable games for different animal species playing together. This is a challenging requirement, as different species understand their surroundings in a different way and react differently in front of the same situation. The design of this kind of games should be informed by previously studying the relationships and playful dynamics of the involved species. Nonetheless, there might exist some cases where the playful interaction cannot be performed due to several reasons: physiological incompatibility of the animals, opposed behavioral reactions, etc.

Despite the difficulties introduced by species variability, ACI studies should take advantage of these differences when it comes to perception and motivational factors. Existing playful games have already tried to appeal to the animals' sensing acuity, capturing their attention with visual clues like moving objects, audio commands or sounds. However, it remains to be studied the effects of different types of stimuli in the animals' attention regarding its species, in order to give a detailed classification which could inform the development of future engaging playful scenarios. Some questions to be addressed are:

- Which is the most appropriate mechanism to start the interaction with the playful environment for a specific animal species? How can this mechanism vary among species?
- Which stimuli are more adequate for each animal species in order to capture and maintain the animal's attention during the game?
- How can animals be motivated to perform some specific activities/tasks during the game? How are these motivational factors influenced by the animal's species?

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### *4.3 Broadening the Horizon: More Devices, More Fun!*

The reported games rely on a single electronic device to interact with the animal. Only *Feline Fun Park* and *LonelyDog@Home* introduce more than one device to entertain the animal, but still there is no communication between the different devices being used, nor a coherent relation between them. Animals playing with the same device over and over again are likely to become bored or lose interest when the novelty factor vanishes. The same could happen eventually with several unrelated devices in the same environment.

An intelligent playful environment should be comprised of not only several and diverse devices, but also interconnected and meaningful. The devices conforming the intelligent environment should be able to cooperate and communicate with the system and the other devices, in order to create elaborated activities which can vary from one iteration to the next one. As an illustrative example, we could think of an intelligent playful environment including several electronically controlled balls, a flying drone with a camera, and an electronic pet feeder. The goal of the interactive game would be to teach sheep-dogs to bring the flock to their masters and learn commands that are commonly used in this task. In this case, the electronic balls would represent the flock and would move according to the behavior that needs to be taught. A sound system would reproduce voice commands and the drone with a mounted camera would track the behavior of the sheep-dog by using computer-vision algorithms. If the dog would not act as previously trained, the system would notify this situation so that further training would be later performed with the presence of a human master. However, if the sheep-dog reacted as expected a reward would be given by the automated feed machine. Having several interactive balls would allow the simulation of different real situations that may occur with real flock that needs to be kept under control. The flying drone would also control the position of the electronic running balls so that they move in a challenging way depending on the capabilities of the dog being trained. The coordination of several devices in this scenario would allow the autonomous training of sheep-dogs when master trainers may not be present.

The final goal/s of the activity will help to identify which kind of devices would make sense together. The system should learn how to better connect and join together the different individual devices, and how to evolve the game when required.

### *4.4 Decision Making and Adaptation: Who Controls the Controllers?*

Although some of the aforementioned games allow the human user to modify several options such as movement direction of the objects, releasing treats, etc.,

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these are just straightforward *ad hoc* configurations. When the human does not intervene, the system can run the game with the default configuration without any major concern. However, having multiple interconnected devices will significantly increase the configuration possibilities, and the human user will not always be participating in the playful experience to control or guide the decisions of the game. As a consequence, the system should intelligently manage the resources and take control of the decisions, adapting the game to the context and the current players, such as in the sheep-dog example in Sect. 4.3, where the electronic balls adapt their movement to the command to be practiced.

Context-awareness and adaptation should be performed in the same way as AmI scenarios adapt themselves to human users: by extracting knowledge from the users' interactions with the system. None of the presented games in Table 2 apply any type of reinforcement learning from the inputs of the system. The construction of future intelligent playful environments should consider these interactions as essential inputs for the learning subsystem.

Nevertheless, not all the responsibility of the game creation should rely on the learning capabilities of the system. There are many situations where the system may not have the best information to take a decision. Moreover, not all the possible scenarios can be controlled or anticipated. Specially, external knowledge from the human users could be essential in the first attempts of the environment to create a new game, when the learning algorithm still has no information. Hence, human users should also be provided with an adequate way of participating in the decisions beside the need for learning algorithms to implement context-awareness in playful environments. Human users without programming experience should be able to manage the environment and define explicit behavior to inform ambiguous decisions, or specify particular scenarios. HCI techniques and studies have already been applied in order to come up with easy-to-use and useful interfaces to allow the definition of explicit behavior by end-users (García-Herranz et al. 2010; Maternaghan and Turner 2011; Catalá et al. 2013). The same philosophy could be applied to bring intelligent playful environments with explicit knowledge from the human participants.

## 5 Application Scenarios for IPE4A

Considering the described requirements and features that intelligent playful environments for animals should accomplish, and after studying the lacks and limitations of existing approaches, the scenarios in which these systems can be deployed have been analyzed and the benefits they can provide in different domains are presented here.

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## *5.1 Mental Well-being*

Not only humans but also animals need to socialize. However, domestic pets spend most of their day alone at home without interacting with their human friends. Even when the human is at home they may not receive all the affection they need. Similarly, zoo animals live inside a restricted ecosystem, sometimes being the only one of their kind and without being able to interact with humans on the other side of the glass in any way. Another risk group are animals living in shelters (Mancini and Linden 2014), where volunteers are unable to give all the animals the attention they require due to lack of resources and people. All these animals can suffer from isolation, sadness and anxiety (Schwartz 2002; Schwartz 2003; Amat et al. 2014), far from achieving a fully happy existence. An intelligent playful environment could detect whether an animal is becoming bored or stressed, and study the best way and best moment to create fun activities to stimulate and entertain him and keep his mind active. For this purpose, the intelligent environment should have previously learned the animal's favorite games and interactions and the most effective sense clues to gain his attention. However, these kind of playful activities, the moment when they are conducted and the consequences on the animal's well-being should be studied in depth in order to avoid behavioral problems or causing stress.

## *5.2 Physical Activity*

Another crucial element to enhance animal well-being is physical activity, which has to be stimulated in cases such as the ones described above when the animals do not receive all the required attention for long periods of time. When an animal does not receive any external stimuli or is feeling depressed, it would not feel like initiating physical exercise. In this case, the environment could capture the animal's attention and engage it in playful activities to make it move and perform some physical exercise. The system could adapt the exercise to the animal's physical attributes and habits in order to create a healthy and amusing routine. Other variables to be taken into consideration should be the frequency, duration and time when the activity should take place. The potential improvements the environment could bring on animals' welfare should be studied considering the aforementioned factors in Sect. 3.

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## *5.3 Training*

Playful environments can also be an enjoyable way of fostering training activities without overloading the animal with strict orders. Tough training and repetitive activities can cause loss of attention and refusal to participate. By transforming the learning activity into a game, it would not be presented as a mandatory and strict activity, and animals might be more inclined to participate. Using playful activities for training could also alleviate the animals' stress and sense of responsibility derived from such a demanding task.

The design of intelligent playful environments for training scenarios should be carried out with the guidance of a professional trainer. Intelligent environments for animals should allow playful training with or without the presence of a human. In case of pet owners, not skilled in training activities, the environment could help them to perform successful practices. The owner's participation in the activity could also reinforce his bonds with the animal. However, some animals will not have the opportunity to be trained by playing with a human, such as in shelters where few volunteers have to attend hundreds of animals. The environment should then be responsible of teaching new behaviors to the animals, adapting the training to their learning pace and motivation.

## *5.4 Therapy*

Animals can help in the rehabilitation of people recovering from illnesses or disabilities (Filan and Llewellyn-Jones 2006; Kamioka et al. 2014). Interactions with animals can reduce patients' anxiety (Barker and Dawson 1998) or help children with autism in socializing tasks (Solomon 2010). In the digital era where we live, some rehabilitation tasks rely on computer-based technology (Leo and Tan 2010). Understanding animals' interactions with computer-based systems could help to introduce animals within these therapeutic activities, e.g., incorporating animals in the context of rehabilitation tasks for people with disabilities such as brain acquired injuries, or creating playful health oriented activities with animals for elder people.

In situations where the animal cannot be physically present with the subject the playful environment could serve as a bridge to bring the patients closer to the animals. Patients could remotely interact with the system via a human-computer interface, by activating devices in the environment or responding to the animals' interactions. As a consequence, some sort of non-verbal communication could emerge between humans and physically distant animals, originating an enriching experience for both sides.

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## 6 Challenges and Considerations

Developing intelligent systems capable of adapting themselves to the context requires ensuring several safety aspects. The system should not harm the environment nor the users in any possible way. This is of special relevance when users cannot be taught how to use the system, and thus, free interactions and behaviors are allowed. *Therefore, the system should respond to the predefined interactions only. Unexpected behavior must not trigger any reaction of the system.*

As has been previously defined, playful systems could allow the animals to play without human supervision. It implies that the animals could be the ones who decide when to start the game, or end it. However, animals may not be conscious about the emotional or physical effort the activity is demanding from them. For example, if a dog is playing a throw-and-catch ball game, which they usually love, it will not stop demanding another round unless it gets exhausted. This physical fatigue may eventually become dangerous if it happens repeatedly. *The system should control the animals' physical activity in order to avoid exceeding the limits of what a healthy exercise should be.*

Another potential pitfall when allowing the animals to play without human supervision is the material damages that they can unintentionally cause in their environment. The game should be conducted within a safe area where physical objects, such as furniture or electrical amenities, do not interfere in the activity. Otherwise, the animals may collide with these elements, injuring themselves or damaging them. *For these reasons, the system or the human should define the physical boundaries of the playing area. The devices involved in the game should be placed within this area, and their operational range, i.e. the area where the animals will interact with the device, will not surpass the defined limits. Potential dangerous objects for the animal should not be placed within this area. Moreover, fragile or valuable objects shall not be placed either in the playing area in order to avoid unwanted consequences*.

When addressing animal safety, we are not only considering physical welfare: mental wellbeing should also be guaranteed. Even if the game does not demand hard physical exercise, the animal could get extremely excited because of the joy it is experiencing. Enjoying the playful activity is essential, but the excitement levels should not exceed the limits of what is salutary. Expending long periods of time under these conditions, inadequate playing schedule (such as allowing play when the animal should be sleeping), or even an abrupt termination of the game by the system could led to stress, anxiety and/or overexcitement. Humans are able to handle these undesired feelings, calming themselves down and returning to a more peaceful state. However, animals may not manifest the same kind of self-control over their emotions and the physical response these emotions trigger. *In order to avoid unhealthy mental feelings, the emotional states of the animal should be gathered. The playful environment should detect whether the animal is entering into an undesired emotional state, readapting the activity to take the animal back to a more relaxed situation. Moreover, some limitations should be defined on the schedule and duration of the playful activity, either by the*

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*humans or by the system. It will help to create a healthy routine, avoiding bad behaviors derived from inadequate schedules.*

The potential of emotion identification is only comparable to the difficulty of conducting such a complex task. Identifying emotional states is a challenging requirement for any kind of system, although there are some successful results concerning human emotion (Picard 1997; Mocholí et al. 2007). Within the animal domain, the physical evidences of an emotional state may differ from one species to another. Nevertheless, for each species there might be some physical parameters which could help to identify their emotions. We could classify these parameters into two different categories: observable and measurable. Examples of observable parameters are ear position, body posture or tail movement. The aggressive emotional state of cats is easily identifiable using observable parameters: ears back, open mouth showing teeth and bended body. Regarding measurable parameters, we could refer to the heart rate or the number of times per minute an animal waves its tail. Excitement, for example, is an emotional state which could be better identified using measurable parameters. However, gathering measurable parameters imply the animal has to wear specific devices, which could be obtrusive and interfere with its normal life. In contrast, observable parameters will require using cameras and sophisticated image recognition methods, which could restrict human privacy in shared environments. *The identification of emotional or mental states in animals, and its use in the adaptation of the playful environment should be carefully studied for each case, analyzing the benefits and trade-offs its deployment could lead to.*

The intelligent playful environment must, in all cases, be unobtrusive both for the animals' and humans' lifestyles. The animals' natural behavior must not be biased nor interfered by the devices which form the environment and the mechanisms used to gather information about them. Domestic animals are more used to face new objects and even digital elements in their daily routines. However, wild animals live in natural ecosystems, being unaware of the existence of any digital elements. Similarly, semi-wild animals use to live in either delimitated areas, like farms, or in artificial spaces which reproduce their real ecosystems, like zoos. Semi-wild animals may be used to human presence or even cameras, but the interaction between them and the digital world is limited, if not inexistent. *If any technology is intended to be used within these environmental conditions, the animal must not perceive it as a potential danger. One way could be introducing the different elements conforming the playful environment gradually, i.e. one at a time and introducing the next element once the animal has become used to the previous one.*

## 7 Conclusions and Future Work

This work proposes a new line of research in the recently emerged field of Animal Computer Interaction: intelligent playful environments for animals. These environments will ground on the most inherent behavior of animals: play. Around

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playfulness, an intelligent environment will generate engaging games for animals. The environment will learn from the animals' interactions, adjusting the game to their needs and requirements. The playful activities created by these environments could help animals to overcome possible issues such as isolation, poor physical condition, repetitive training exercises or remote digital interaction with human-beings. Moreover, we believe that intelligent playful environments for animals would be the perfect scenario in which to study animals' interactions with digital devices, as the animals will engage voluntarily in the playful experience. The benefits derived from IPE4A could apply both to human and animals' well-being.

A conceptual taxonomic framework has been laid down for the future design and development of these environments. Existing games based on technology for animals have been analyzed in terms of the proposed framework, detecting some shortcomings that intelligent playful environments could help to resolve. Several applications have been outlined, highlighting the benefits of applying intelligent playfulness to animals' interactions with digital ecosystems.

Future work essential for the successful construction of IPE4As includes the definition of a formal development methodology covering the aforementioned features and requirements. Each of these features should be carefully studied in order to determine how they will affect the construction of the environment and the users' well-being, and whether they should eventually be taken into consideration in the development process regarding the specific circumstances.

The first step for the design of intelligent playful environments should be studying the most fundamental game phases, which will be common in a range of playful experiences that could be created. Considering the playful activity as a story/performance in which the actors will be the animals, the most basic and common phases in which we can decompose such stories will be the introduction, development and conclusion. Therefore, the most fundamental interactions within an intelligent playful environment will be the initiation of the activity (introduction), the transition from one stage/goal to another (development) and the termination of the game (conclusion). A set of experiments is being designed to study these three game phases that every playful experience contains. These experiments aim to answer some of the questions raised in Sect. 4.1: how could the environment gain the animals' attention and whether animals would be willing to initiate the playful interaction. These experiments will also study how different types of stimuli affect the animals' engagement in each of the three aforementioned game phases. For this purpose, we will evaluate the animals' reaction to smell, sounds, lights and moving devices in order to find the most suitable interaction for each context.

In addition, we are defining in our on-going work a flexible intelligent behavior-management system for reactive environments. It will learn from the users' habits and preferences, extracting behavioral rules. The human end-users of the system will also be able to define their own personal behavioral rules and incorporate them into the environment. The behavior-management system will therefore combine two ways to incorporate behavior based on automatically acquired knowledge and explicit knowledge specified by humans. This powerful combina-

tion will allow the development of playful environments able to adjust to a wide range of situations more effectively, without having to develop a specific system for each scenario.

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