

ViPleo and PhyPleo: Artificial pet with two embodiments

[Author-prepared version]*

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ABSTRACT

In our current work we have designed and implemented an artificial pet with two embodiments. In both embodiments behavior is driven by needs that are used to maintain coherence and motivate user interaction. These needs are transferred between embodiments, with only one embodiment being active at a time. We performed an evaluation with 10-year old children participants. The retrieved data indicated that many children understood the concept of an artificial pet with two bodies, even without being given clues. Nevertheless, children did perceive differences between the two embodiments, which contributed for many stating that they interacted with two pets. Among other aspects, the physical version was perceived as less obedient due to problems concerning action recognition. Although caused by technical

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issues, this result raises the question if virtual embodiments should simulate action recognition problems that their physical counterparts have.

Categories and Subject Descriptors

H.5.m [Information Interfaces and Presentation (e.g., HCI)]: Miscellaneous; I.2.9 [Artificial Intelligence]: Robotics; I.2.11 [Artificial Intelligence]: Distributed Artificial Intelligence—*Intelligent agents*

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Human Factors, Experimentation, Design

Keywords

Human-robot interaction, migration, mobile and ubiquitous entertainment

1. INTRODUCTION

Since the great success of the Tamagotchi¹ in 1997 [15], the concept of virtual pets has grown to a widespread awareness. There were other cases of considerable commercial success: more than 7 million Nintendogs labeled games sold worldwide; the on-line pet nurturing website success Neopets² [18].

Inspirational to these games, actual human-animal interaction has been proven to have numerous benefits. Some former cancer patients attribute part of their cure to their

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pets [11]. It is argued that owning a pet can decrease systolic blood pressure and plasma cholesterol [1], as well as reduce the probability of having cardiovascular diseases [19]. Animals have already been used in Animal-Assisted Therapy to fight dementia, loneliness and, even Alzheimer’s disease [21]. Moreover, animal contact during childhood, can improve the development of communication skills [9].

In spite of all these benefits, their training requires considerable human resources, money and time. Additionally, when many people and animals are put together, safety and hygiene become quite difficult to control. These are particularly relevant issues in health care facilities. Furthermore, there are always certain safety risks linked with the unpredictability of animal behavior.

In opposition, a robotic pet does not present such drawbacks. One such robotic pet is Pleo³, that has a toy dinosaur appearance, touch sensors, several motion motors, speaker capabilities, and some limited object recognition attributes. In a study considering this robot, it was shown to have some limitations in what concerns keeping users engaged for long periods of time [8]. Some of the issues revealed were the following:

- short battery duration: the battery lasted around one hour and took about four to charge. This issue was particularly upsetting for children.
- battery maintenance was not integrated with play: while children were playing with Pleo, the robot would sometimes freeze due to the lack of battery, and an adult would have to interrupt play to change it.
- unfulfilled expectations: participants had very high expectations about the robot’s response to voice commands, its ability to train and its mobility. In part fueled by company marketing information, these were largely unfulfilled.

Regardless of these issues, the robot appears to have potential for maintaining some affective connection with users. In another study that analyzed posts in Pleo user forums, situations were identified in which users, when faced with a malfunction, preferred voiding their warranties and fixing the robot themselves, rather than sending it to support and risking not getting the same one back [10].

Some of the issues revealed can possibly be transposed to other robotic pets. Considering the potential of robotic pets, their limitations, and the commercial success of virtual pet games, we were motivated to design an artificial pet with two embodiments: a virtual embodiment in a hand-held device and a physical embodiment. With such a structure new ways of addressing the two first mentioned issues, and in the end of maintaining the interaction flow [5], could be devised (e.g. the artificial pet’s mind could go to the virtual embodiment when the physical embodiment was low on battery).

More generically, having multiple embodiments for an artificial pet can be used to complement the functionality of such embodiments. For instance, having an additional mobile embodiment to an existing robotic pet may increase the pet’s portability, and at the same time maintain the unique interaction style that a robot allows. Furthermore, adding a new embodiment can be used to extend the pet’s capabilities when the original embodiment has inherently strict

limitations. For example, in the hand-held device the pet might be able to access the internet’s resources, when this possibility was not incorporated in the original robot. To finalize, as today’s robots still have mobility restrictions, and battery duration limitations, we believe that analyzing dual embodied pets can help us understand how to better design artificial pets in the future.

2. RELATED WORK

Artificial pets with a virtual embodiment have been studied in educational contexts. Examples of such use are My-Mini-Pet [16], My-Pet [4] and Virtual Polar Bear [6]. In My-Mini-Pet and My-Pet, the game’s progress and pet’s growth depends on the user successfully completing subject specific tasks (e.g. solving simple arithmetic expressions). In the case of the Virtual Polar Bear, the user is faced with environmental decisions, and according to them the ice floe in which the bear lives increases or decreases. In these applications, the possibilities of how a user can attend to the virtual pet’s needs are quite limited. Furthermore, the artificial does not have a physical embodiment.

The idea of an agent having different embodiments was explored in [17]. Here agents would teleport between geographically separated locations, and in each location interact with one another. The agent’s mental state, that included a lexicon and concepts, was transmitted over the Internet. Through the interaction, the agents create a community knowledge base, gathering input from the different locations. Related to the concept of teleportation, is the concept of migration: an agent interchanging between different embodiments, even if they are physically close. In [14] the perception of migration from school students is studied in regard to the migration of an agent between two robots. The display of an ‘energy bar’ decreasing in the departing robot, and increasing on the arriving robot, and alternatively a smiley face passing from one display to another, seemed to transmit the idea of the agent’s transition. Nonetheless, in these examples a border between virtual and physical world is not crossed: there is not both a physical and virtual embodiment.

The authors in [20] considered an object that exists both in the real world and on a screen. In the considered scenario the user controls a robot in a mixed reality game. The robot can interact with a ball that moves between the real world and a virtual environment: it is projected on the floor in the real world, and is displayed as a three-dimensional object on a screen wall in the virtual environment. There is a strong emphasis on maintaining the continuity of movement when the ball passes between dimensions. Additionally, virtual characters with similar physiognomy and animation to the controlled robot are displayed in the virtual environment. These are responsible to push the ball back to the physical space, maintaining a Pong like game. It is claimed that the physical embodiment, and the ball, serve as links to the virtual world, potentiating how immersed a user can feel in it. However, the transition of an actual character between physical and virtual worlds is only discussed as future work.

Lastly, in [7] the authors considered a virtual and physical version of an artificial pet, having similar motivations to those of our work. However, there was no actual migration between physical and virtual embodiments.

In conclusion, despite research on virtual pets, migration, and mixed reality entertainment, we believe combining these

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Figure 1: Petting (left) and feeding (right) in PhyPleo

elements in an unified prototype and analyzing its capabilities, is a fresh perspective in the field of computer entertainment.

3. TWO EMBODIMENTS

When designing the artificial pet, we followed a soul-shell approach [13]: the embodiments serve as a shell to the pet’s *soul*, with the pet only being active in one of the embodiments at a time. This *soul* should be reflected in both embodiments in a consistent way.

The analysis of commercial virtual pets served as a good starting point in defining this *soul*. In [12], the author points out that successful commercial artificial pets tend to try to make the owner feel guilty if he, or she, does not take care of its pet. Additionally, he suggests that pets should have an interaction need: the pet may present exploratory behavior, but when the need is active, the pet starts to seek the owner’s attention; additionally, when the owner gives the demanded attention, this need would cease to be active.

In line with Kaplan’s ideas, and also with the desired consistency, in both embodiments the behavior is driven by needs. The current needs are the following (organized into the PSI-Theory categories [2]):

- Preserving needs: energy, water (thirst) and cleanliness;
- Affiliation need: petting (need for affection);
- Competence need: skill;

Each need has a corresponding numeric value that ranges from 0% (need completely unfulfilled) to 100% (need completely fulfilled). For instance, an energy value close to 0% would represent that the pet was starving.

Currently we have an artificial pet (Pleo) that migrates between a robot embodiment (PhyPleo) and a virtual version on a mobile phone (ViPleo). Only one embodiment is active at a time: when ViPleo is activated, PhyPleo freezes; when ViPleo is deactivated, PhyPleo reactivates. In Table 1 we present a description of possible user actions in both embodiments (with visual representations in Figure 1 and Figure 2) and the effect they have in need values. Additionally, to the functionalities described in the table, ViPleo will poop a while after eating, which decreases its cleanliness value. Besides being affected by user actions, in both embodiments the energy, water, cleanliness and petting values decay. The decay is the same for PhyPleo and ViPleo. In Table 2 we present how the influenced need values determine the pet’s behavior. Lastly, in ViPleo the need values can be visualized as a graph bar.

4. ARCHITECTURE AND MIGRATION

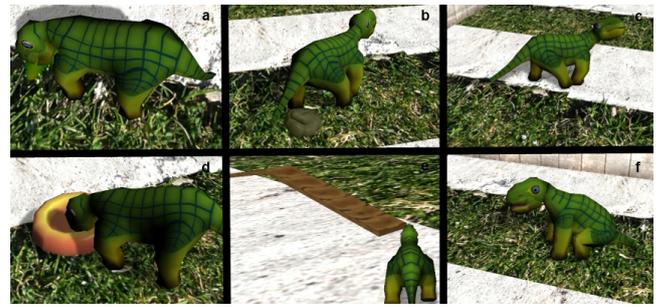


Figure 2: ViPleo’s Behaviors - eating (a), pooping (b), being petted (c), drinking water (d), going through an obstacle course (e), sitting and crying (f).

The artificial pet with its needs is schematically represented in Figure 3. PhyPleo’s behavior was defined in Pawn script using the robot’s operating system (LifeOS⁴) SDK. It was not possible to extend the robot’s original behavior with additional functionality because we did not have the original code, nor the possibility of linking a compiled version of it to our code. The behavior was based on one of the example behaviors supplied together with the SDK.

Need values are stored in a property section of memory. These properties are accessible by all scripts running in LifeOS as well as from the exterior via the monitor interface. We connected to this monitor interface via a serial connection (UART) linking a bluetooth dongle to it, thus enabling wireless communication with the robot.

ViPleo, on the other hand, is an Android⁵ application written in Java that has a module using the Shiva3d graphical engine⁶. This module is the interactive part of the application and is internally scripted in Lua. The android application is responsible for communicating with PhyPleo, loading the needs values from an xml file in which they are stored persistently, and starting up the Shiva module.

When the Shiva module is started, the need values in the xml file are loaded to local variables. These variables are updated according to the user interaction and to the previously mentioned decay with time. When the Shiva module is exited, the values on the local variables are used to update the xml file.

The migration between embodiments is conceptually performed by sending need values via Bluetooth. Need values are only sent when one of the embodiments is activated (and the other deactivated). The migration process is triggered in the hand-held device. For the migration to take place, the robot must be turned on and the Android application running.

We present the steps of the PhyPleo to ViPleo migration:

- Need values in LifeOS properties are requested via Bluetooth by the Android application;
- These values are sent to the Android application via Bluetooth;
- In ViPleo the values in *needs.xml* are overwritten by the received values;

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Table 1: User actions in both embodiments (PhyPleo and ViPleo)

Action	PhyPleo	ViPleo	Need effect
feeding	Inserting an object into its mouth (Figure 1 right).	Placing a patch of leaves in the virtual playground. Pleo moves towards the path of leaves and then eats it (Figure 2.a).	energy increased
petting	Touching its skin in sensor locations (Figure 1 left)	Touching the screen in the area in which Pleo is shown (Figure 2.c).	petting increased
wash	(not implemented)	Removing any poop that might be in the playground.	cleanliness increased
water	(not implemented)	Placing a water bowl in the virtual playground. Pleo moves towards it and then drinks from it (Figure 2.d).	water increased
train	(not implemented)	Playing a mini-game that consists of taking Pleo through an obstacle course (Figure 2.e).	skill increased

Table 2: User actions in both embodiments (PhyPleo and ViPleo)

Need & value	PhyPleo	ViPleo
energy low	sniffs the ground, bites downward and slowly moves forward	sits down and cries (Figure 2.f)
petting low (energy not low)	gives discontent growls	(not implemented)
neither of the above	waggles its tail and gives high pitch barks	walks around the playground

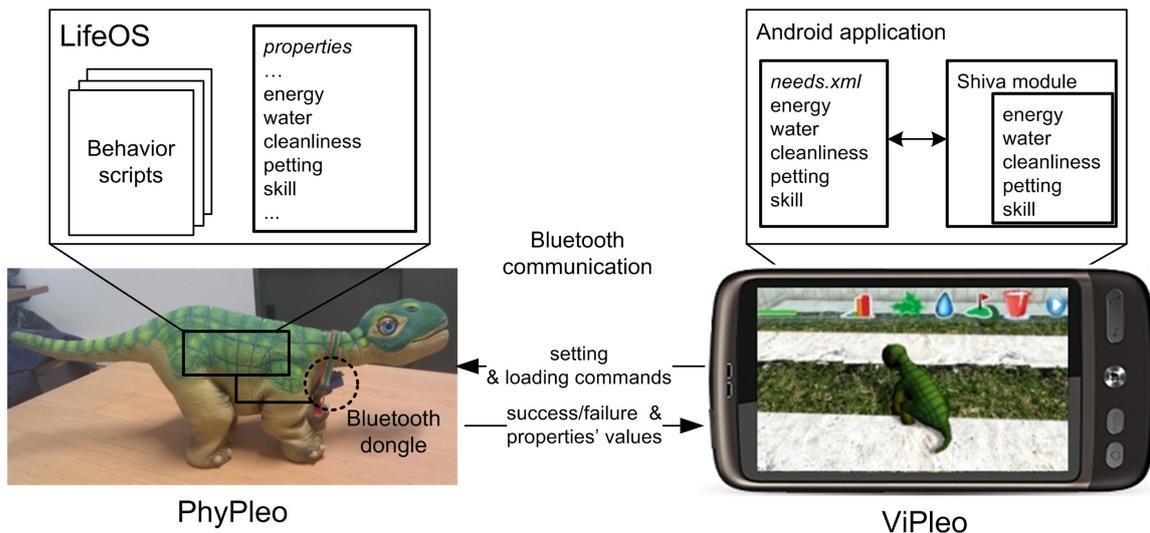


Figure 3: Architecture Overview and Migration

- The Android application sends a command to PhyPleo so that an “empty behavior script”, in which Pleo stands still, is loaded;
- The Shiva module is started;
- Need values are loaded from the xml to the Shiva module;

The migration from ViPleo to PhyPleo has the following steps:

- Local need values in the Shiva module are stored in the xml file;
- The Shiva module exits;
- The Android application loads the need values from the xml;
- Setting commands for the need properties are sent via Bluetooth to PhyPleo;
- The Android application sends a command to PhyPleo so that the “empty behavior script” is unloaded and the normal behavior of the pet is performed;

Commands sent to the monitor interface have a tendency to be received with noise due to the serial connection being prone to electro-static discharge. Additionally, if the monitor receives too much noise it shuts down. Moreover, the monitor can only be reused after the robot is turned off and on. To address this issue, when the Android application sends a command, it waits for a command success acknowledgment. A lesson learned from these problems could be that if a robot’s interface detects too much noise, it should not simply turn off. It should probably first try to call attention to the problem, and the shutdown behavior should be settable somehow.

5. EVALUATION

We performed two evaluations with the described artificial pet: in the first we explored how adult owners of a virtual pet felt towards the possibility of having a second embodiment for their robotic pet; in the second evaluation, we explored too what extent children could understand the concept of an artificial pet having two bodies.

5.1 Preliminary Evaluation

We performed a preliminary evaluation of ViPleo with participants already familiar with the Pleo robot. This study was performed before migration was fully functional, and with it we explored three items: if users perceived ViPleo as being similar to the Pleo robot; if users valued a second embodiment of the artificial pet; and if ViPleo could potentially bring them more comfort.

First, participants answered a questionnaire regarding their own Pleo robot. Then, a description of the project was presented to the participants defining the setting of ViPleo. Next, they were asked to play a web version of ViPleo and to imagine they could use such an application to interact with their own Pleo. They could play for as long as they wished (on average participants played for 37 minutes). After playing, they answered the same set of questions as before. Finally, they were asked other questions specifically regarding ViPleo.

Participants were recruited from the on-line forum, bobthepleo [3]. There were 26, with ages ranging from 23 to 44, 58% of which were male. Most of the participants reported interacting with the Pleo robot at least once a week (73%), and almost all had the robot for more than one month (92%).

To evaluate the potential comfort that ViPleo could add to the user-pet relation, we asked participants to rate their level of agreement (five point likert scale) with phrases adapted from the “Comfort from Companion Animal Scale (CCAS)” [22]. The CCAS was initially created to measure attachment of an individual towards a live pet. We compared results before, and after interacting with ViPleo.

In Table 3 we present the phrases, the mean ratings before and after interacting with ViPleo, as well as the significance of the two being different according to a Wilcoxon signed-rank test. Considering an α -level of 5%, results were significantly different for questions 2, 3, 5 and 6. In these cases the mean was higher after interacting with ViPleo (higher level of agreement).

Participants were also asked to rate how well they understood Pleo’s expressive behavior before, and after interacting with ViPleo. With an analogous analysis as the just presented, the mean rating after interacting with ViPleo was significantly higher ($p < 0.05$). Additionally, we asked how much users would enjoy carrying Pleo, and again the mean was significantly higher ($p < 0.05$) after the interaction with ViPleo. Finally, concerning the questions specifically aimed at ViPleo, 84% agreed that ViPleo was similar to the Pleo robot, and 73% of the participants would value interacting with ViPleo if the robot’s battery charge was low.

In conclusion, the results appear to indicate that Pleo robot adult users would value having a second embodiment for their artificial pet, and that this duality could potentially contribute to an enhanced feeling of comfort. However, participants had to answer “as if” they had the artificial pet with two embodiments, which may affect the result’s validity.

5.2 Second Evaluation: PhyPleo and ViPleo

This second evaluation was carried out after the implementation of migration, so in opposition with the previous one, participants were exposed to both PhyPleo and ViPleo. Our aim in this workshop was threefold: i) exploring the way children understood the companion and the process of migration ii) their assessment of the game experience, and iii) their assessment of their relationship with the pet. We will be focusing on the first topic, and thus will describe the evaluation focusing on elements relevant to it.

We considered that if a child understood the companion as being only one entity, when asked about how many dinosaurs it interacted with, the answer should be one. Additionally, when testing the evaluation structure with 6 children, we had comments that indicated that ViPleo was perceived as more obedient and PhyPleo as more independent. The two hypothesis we considered were consequently the following:

1. Children indicating they interacted with only one entity after being exposed to the prototype.
2. Children rating the ViPleo embodiment as more obedient than the PhyPleo embodiment.

The evaluation was performed with 10 year-old children from two classes of the same school, 51 in total. There were 25 sessions, each of them of approximately half an hour.

Table 3: Wilcoxon signed-rank test for adapted CCAS

Phrase	p-value	before (mean)	after (mean)
1. Pleo provides me with companionship	0.564	3.12	3.20
2. Pleo provides me with pleasurable activity	0.033	2.80	3.20
3. Pleo is a source of constancy in my life	0.011	1.72	2.36
4. Pleo makes me feel needed	0.559	2.28	2.40
5. Pleo makes me play and laugh	0.001	2.00	2.88
6. I enjoy watching my Pleo	0.040	2.92	3.36
7. Pleo makes me feel loved	0.378	2.24	2.40
8. Pleo makes me feel trusted	0.216	3.48	3.76
9. Pleo makes me feel safe	0.415	2.08	2.24
10. I get comfort from touching Pleo	0.378	3.72	3.88

There were two children per session (except for one session, consequence of the uneven number of children). The sessions were video recorded with two cameras positioned orthogonally (see Figure 4).

The children were told a storyline to motivate their interaction with the companion. They had to imagine that a neighbor had left Pleo to their care. The neighbor supposedly told them to keep track of how many times it was fed, and also that it liked being petted. Apart from that, they could interact as they wished. Later on, if they asked how to do something with Pleo, the evaluation guide would answer that in the story the neighbor did not say.

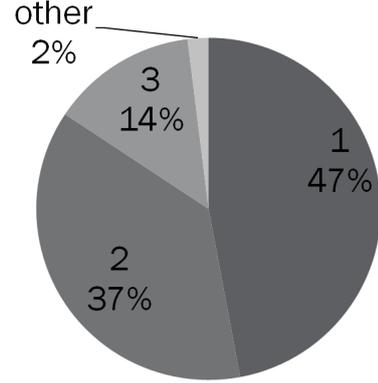
The structure of the sessions had two main parts. During the first one, children would interact with one of the embodiments during approximately 5 minutes. Then, they would do a closed questionnaire regarding their interaction with this first embodiment. This questionnaire was designed mostly using 5 point likert scales. Before answering, children were asked to rate a phrase using a likert scale so they would be comfortable with the method. One of the actual questions concerned obedience versus independence: 1 meant a ‘more independent’ attitude and 5 meant a ‘more obedient attitude’ perceived in the pet.

In the second part of the evaluation they would witness the migration to the other embodiment and could still interact with the artificial pet. After that, they answered more likert questions and the evaluation guide performed semi-structured interview. In this interview they were asked about how many dinosaurs they interacted with. In order not to guide the answers in any specific direction, more effectively assessing how intuitive the migration concept was, the concept was not described at any time. Furthermore, in the second part of the evaluation children were not told that something would happen in the second embodiment, only that they could interact with it (we actually used the term ‘here’ instead of ‘this’ not to induce individuality of the embodiment).

The embodiment used in the first part of the session was changed every other session to be able to compare the two embodiments in isolation. Additionally, this choice contributed that on average the answers to the semi-structured interview were not excessively influenced by one of the embodiments alone (the one being interacted with last).

Results

Concerning the number of dinosaurs, there were about half claiming to have interacted with one (47%). The frequency distribution for this question is presented in Figure 5.

**Figure 5: Number of dinosaurs**

Concerning the obedience question, we conducted a *between groups test* (Wilcoxon Rank-Sum/ Mann-Whitney) comparing the answers from children interacting first with ViPleo, to children interacting first with PhyPleo. For this test we only considered answers from the questionnaire of the first part, in which children had only been exposed to one of the embodiments. In the comparison, ViPleo presented significantly ($p < 0.05$) higher values for obedience than PhyPleo, with a large effect size ($r > 0.5$). This difference can be identified in the box-plot of Figure 6.

Discussion

The data does not seem to support our first hypothesis: about half of the children considered there was more than one dinosaur. However, we must take into account that the concept of migration was not explained to the children. Faced with two separate objects, children had the challenge to abstract the concept of a common entity. In a more natural scenario, upon receiving an artificial pet with two embodiments, there would probably be indications, clues, of such a process. Having this in mind, we believe that the retrieved data indicates that for children of the considered age, the concept of an artificial pet is probably easy to grasp if it is to be explained.

Nevertheless, it is interesting to analyze the reasons that led to the perception of two different entities. The different perception of obedience is probably one of them. The data supports our hypothesis that ViPleo is considered more obedient. During the interviews, children claimed that PhyPleo

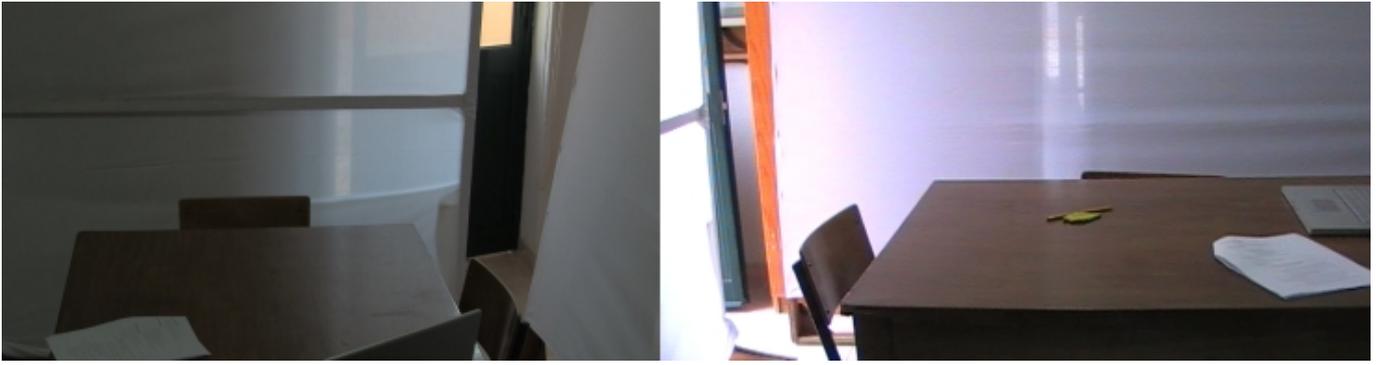


Figure 4: Second evaluation cameras

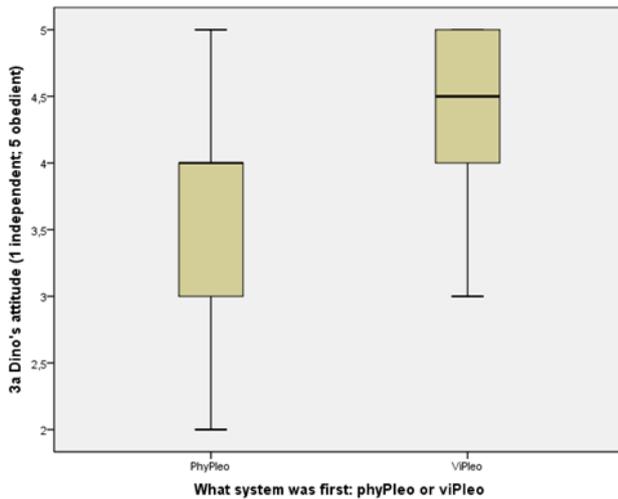


Figure 6: Obedience in PhyPleo and ViPleo

did not always obey them. Namely, that it would sometimes decide not to eat, even when presented with a leaf. When looking at the videos, two types of situations appeared more relevant to this phenomenon: when PhyPleo was not hungry, it would sometimes coincidentally turn his head to the side at the same time a child would be trying to feed him; some children did not took the initiative to stick the leaf in PhyPleo's mouth as he would not open it that much, nor for that long. Although these were technical issues of the prototype, they apparently gave the illusion of the pet having a will of its own. This fits rather well with Kaplan's idea [12] that we have a tendency to attribute agency to machines that do not work, thus appearing not to be obeying. If we analyze ViPleo from the same perspective, it always obeys: it always goes to eat when we give him a leaf.

We believe that one possible idea to take from this, is that if we have a companion with two embodiments, and one has problems recognizing certain actions, then the other should possibly try to simulate such problems, or have alternative mechanisms of appearing to be not obedient. That is, if we are truly interested in having a one entity perception. Of course if pure action responsiveness is more important than such mechanisms should not be added.

6. CONCLUSIONS

In conclusion, we have designed and implemented an artificial pet with two embodiments. I both embodiments behavior is driven by needs, that are used to maintain coherence and to motivate user interaction. These needs are transferred between embodiments during a soul-shell type migration.

We evaluated how adult users of a robotic pet perceived the possibility of being able to interact with a second embodiment of their own pet. Users indeed seemed to be interested in having an alternate interaction method, namely when their robot's battery charge was low. However, they did not actually experience an interaction with the whole prototype, only with the virtual version.

We performed a second evaluation, this time with children and using the complete prototype (virtual and physical). The retrieved data indicated that many children understood the concept of an artificial pet with two bodies, even without being given clues. Nevertheless, children did perceive differences between the two embodiments, which contributed for many stating that they interacted with two pets. Among other aspects, the physical version was perceived as less obedient due to problems concerning action recognition. Although caused by technical issues, this result raises the question if virtual embodiments should simulate action recognition problems that their physical counterparts have, in order to be perceived as having a will of their own.

Future development should include changing the behavior displayed by PhyPleo and by ViPleo so that they are as similar as possible. Moreover, there should be identifiable changes in behavior if any of the needs reach a critical value. Additionally, we hope to use migration to better integrate the robot's maintenance into play. One possibility would be to have the pet appearing to go to sleep in one embodiment and waking up in the other. Finally, the remaining data from the second evaluation, such as the recorded interaction and interviews, needs to be more thoroughly analyzed.

7. ACKNOWLEDGMENTS

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