Revive! Reactions to Migration Between Different Embodiments When Playing With Robotic Pets

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ABSTRACT

This paper explores the issues that arise in the context of the migration of a robotic pet between different embodiments and the associated design challenges. In the following, we describe the perceptions that a group of children have of a dinosaur character crossing the boundary between its robotic embodiment (the Pleo commercial pet), and its virtual counterpart on a mobile phone. We analyse the children's perceptions of, as well as emotional reactions to, the migration of this character, and show how seemingly subtle variations in the migration process can affect the children's perception on the character and its embodiments. Among other findings, gaps in the migration process, or perceived unresponsiveness, appeared to be accompanied by anxiety in the participating children. Based on our results, we point to yet unsolved design challenges for migration in interactions with embodied characters, and offer insights for migration implementation.

Categories and Subject Descriptors

H.5.m [**Information interfaces and presentation (e.g., HCI)**]: Miscellaneous

General Terms

Design, Experimentation, Human Factors

Keywords

Artificial Pets, Human-Robot Interaction, Mobile and Ubiquitous Entertainment

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1. INTRODUCTION

Robotic toys offer interesting possibilities for play, such as responsiveness to user actions, pro-active behaviour, and the ability to learn and evolve over time. However, the adaptive and pro-active behaviour of an evolving 'character' needs to be carefully designed or it will hinder play rather than support it. Moreover, technical maintenance issues, like limited battery life, can also cause problematic interruptions in the flow of play [6].

The migration from one embodiment to another one has been proposed to overcome a number of limitations of current robots. It could allow a character to adapt its physical form to different contexts and tasks [12, 10]. Migration can also mitigate mobility issues of current robots and facilitate more continuous accompanying of users. One of such robots is the commercially available Pleo, a mechatronic dinosaur toy with touch, force-feedback, and tilt sensors, vision system, motion motors, and speakers. For robotic toys such as Pleo, migration between multiple embodiments would allow for mitigating disruptions, and therefore a more pervasive play experience.

This paper explores the issues that arise in the context of a robotic pet that pro-actively migrates from one embodiment to another. Here, we present a follow-up analysis on [7], an evaluation with children of an example implementation of the 'migrating' Pleo dinosaur character, moving from its physical robotic embodiment to a virtual representation on

a mobile device, and vice versa.

In [7] we focused on introducing, motivating, and explaining the design of a second embodiment to complement the commercial Pleo, to which Pleo's character would migrate back and forth. We focused on whether the children perceived one or two pets. Here, we perform a follow-up analysis on additional data collected during that study, and focus on children's perception of the migration process itself. We will delve deeper into the children's understanding of the migration process and their affective reactions, as well as the role of design and implementation aspects in this process. We show how seemingly subtle differences in the migration can affect the children's perception of the character and its embodiments.

2. BACKGROUND

Robotic toys and pets have been around for the last two decades. Early examples include Furby, as well as more advanced 'pets' such as Sony's AIBO ®, and more recently Pleo.

Previous research has showed that both children and adults engage with robotic pets and connect emotionally to them [21, 8]. Pets such as Pleo appear to have potential for engaging users in an affective connection. For example, in a study of 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 [8].

However, it has also been found that kids play with robotic toys/pets such as Pleo and AIBO for a short time but over time the engagement declines[6, 9]. Turkle also found that people fell into two groups, one that played along, and one that didn't. Pleo may also fail to engage a considerable part of users for longer periods of time. Unfulfilled expectations in terms of its responsiveness, trainability and mobility disappointed users in a long-term study of Pleo as a family robotic toy, as did its short battery life, and lack of integration of battery maintenance in play [6].

In [7] we described an approach of combining virtual pets, migration and mixed reality entertainment in the form of a unified prototype of a robotic dinosaur pet Pleo and its virtual embodiment on a mobile phone (see Figure 1). Having several bodies or *embodiments* of one same pet, from which the *soul* of the pet can migrate back and forth can help in integrating the maintenance of the pet into the play, and therefore make for continuity of play [7]. This in turn can help to support more long-term engagement.

Migration of agents between different embodiments, beyond robotic toys, has been explored by multiple authors. In [18] the authors describe agents 'teleporting' between different robot bodies, allowing agents to experience, learn, and act on the world in different embodiments and in different locations. Similarly, the idea of an agent having different embodiments and having agents teleporting between embodiments in geographically separated locations was explored in [15].

Issues of disruption and persistence are not exclusive to migrating robots, but also arise for example in mixed reality settings, or in interaction with mobile devices. Tomlinson et al., [20] describe 'embodied mobile agents': graphically animated, (semi-)autonomous agents that migrate from one device to another, with their evaluation pointing to the engaging nature of an object that migrated from device to device. Robert et al. [17] similarly describe a game in which a tele-operated robot plays with its virtual peers by passing a ball back and forth through an physical and virtual environment.

Figure 1: PhyPleo on the left and ViPleo on the right

The authors above have shown that migration has the potential to facilitate persistent engaging interactions, overcoming mobility or maintenance issues. It allows for an agent embodiment to be adapted to various circumstances and goals [16], and better adaptation to users' needs and their activities [12, 10]. Depending on the task at hand, or users' preferences, agents can migrate into a different physical embodiment [18, 19]. Alternatively, virtual representations can take over, for example in portable devices or phones [4, 7], making for more mobility of the agent by effectively enabling the user to take the character with them, while its physically embodied form 'shuts off'. It could maintain interaction flow [3], a crucial aspect in the enjoyment of play [14] by preserving immersion and control, both of which can be jeopardized by disruptions.

However, the use of migration requires careful design. For example, users might perceive it as they are interacting with two agents instead of one agent migrating [11] and multiple embodiments can cause expectations on behaviour [19]. Studies on how nuances in the design and implementation affect user reactions, and guidelines for designing migrations, are however scarce. We here aim to offer a number of insights in designing migration in play with robotic pets.

3. DESIGN OF MIGRATIONS

In the migration set-up, Pleo transitions between its physical robotic embodiment (here called PhyPleo) and its virtual version on a smartphone (ViPleo[1]). Ideally, only one embodiment is active at a time: when PhyPleo is active, ViPleo 'freezes'; and vice versa. In order to make for a pervasive experience, both embodiments should be perceived by the users as representations of a same character, which is not straightforward. The creation of a character that can be embodied in different embodiments may expand the temporal and spatial aspects of the play, making it a pervasive experience. However, in order to allow for such a pervasive experience, we need the users to *believe* they are dealing with a same companion. For this, we are using common visual cues in the two embodiments and also, inspired by [13], common appearance of goals reflected in the behaviour of the companions.

Both embodiments share the same goals, defined in the form of needs, that shape the behaviour of the pet. Needs include preservation needs (need of food, water, and hygiene), and affiliation needs (need for petting). Values for these are

[1]Android application written in Java. More technical information in [7]

transferred between embodiments and decrease over time unless the user takes action (e.g. touching PhyPleo, or the on-screen ViPleo to pet; or feeding PhyPleo by offering Pleo's leaf, or ViPleo by directing it to a feeding patch). Robot behaviours are shaped by the possibilities and limitations of their embodiment. Therefore, designing for equal behaviour in all embodiments would mean limiting the potential of each of them. We opted for designing for different behaviours that point to the same goals. We defined a clear set of *goals* that both embodiments share, independently of the behaviour designed to reflect those goals. In other words, each embodiment expresses its needs in its own way. For example, when PhyPleo is hungry, it sniffs the ground and bites downwards; when ViPleo is hungry, it sits down and cry.

The pet's needs and state are exchanged between embodiments via Bluetooth. More technical details regarding the implementation of the migration can be found in [7].

4. THE STUDY

We performed a study of the migrating Pleo with 51 children primary school children from the 5th grade (10 - 11 years old) in a primary school in Portugal[2]. The children were grouped in pairs (except for one session in which three children participated, for we had an odd number of children). At the beginning of the session, they were told a story about a neighbour leaving Pleo at their care, to encourage them to start interacting with Pleo. Each session took approximately half an hour. These sessions had two main parts: in the first part, children were exposed to one embodiment for five minutes; in the second part, they were exposed to the same embodiment for one more minute, and then they would witness the migration between that embodiment and the second one (visible but 'off' on the table where they were playing), and finally they would play for five more minutes with this second embodiment. Half of the sessions started with an interaction with the Pleo robot, the other half started with the Pleo mobile character.

The children were interacting with the embodiments on a rectangular table. Each of them was sitting by one perpendicular side of table. Two cameras were recording the whole sessions, each pointing to one of the children's direction. Two researchers were present during the sessions, keeping a reasonable distance between them and the children, so to make them feel free to interact with the embodiments in their own way, but reachable at the same time, in case they needed help or there was a technical issue.

4.1 Measures

In between the first and the second part of the session, we conducted a closed questionnaire, mainly with 5-point Likert-type scales (listed in [7]), focused on the children's perception of the gameplay, and their relationship with the Pleo character, which was persistently referred to as 'Dino' during the sessions. At the end of the second part of the session, this same questionnaire was repeated, this time evaluating the 'whole experience'. These Likert-type scale items were included (translated, Portuguese):
'How fun was playing with Dino?',

[2]For the video analysis of the study reported in section 5, 3 pairs of children have been excluded, as the video recordings for their sessions were corrupted

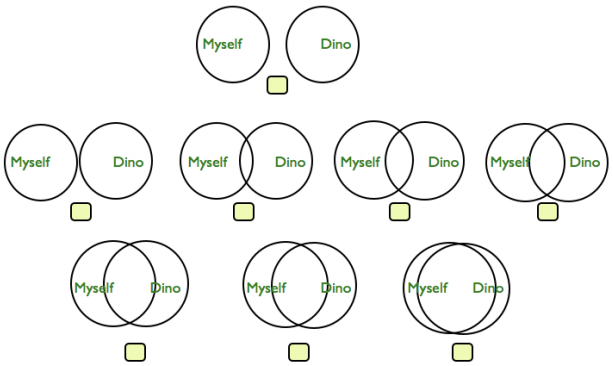

Figure 2: Adapted IOS questionnaire to measure closedness

'How difficult was playing with Dino?'
'How obedient was Dino?'
'How much did you understand how Dino was feeling?',
'How much did Dino understand your actions?',
'How much you liked taking care of Dino?',
'How much Dino liked you taking care of him.
Last, we had a question regarding the *perceived closeness* between the pet and children, using the pictorial closeness scale, based on [1] (See Figure 2). Additional items and analysis of for example companion comfort can be found in [7].

An open semi-structured interview concluded the session. To gain more insight about how the migration was perceived and how that affected the perception of one or two embodiments, we asked the children how many dinosaurs they had interacted with, and also what happened in the second part of the session, when they stopped playing with one embodiment to play with the second one.

Their explanation of the migration was analyzed in conjunction with video analysis of the moment of migration.

A video per session was created, integrating the two camera-views in order to have a good view of the children's gestures and their body reactions. The analysis comprised approximately one minute prior to migration, the migration itself, and the first minutes after the migration, when the interaction resumed with the second embodiment. Three sessions were discarded from the main analysis because of missing or incomplete video material.

To assess the emotional reaction that the children showed due to the migration, we focused primarily on facial expressions and secondary in body movements following Ekman's [5] blueprints of the major motions, i.e surprise, fear, anger, disgust, sadness, and happiness, e.g. the appearance of fear in the face can be shown in the forehead (the brows are raised and drawn together, there are wrinkles in the centre of the forehead), in the eyes (the upperlid is raised, exposing the sclera or the eye, whilst the lower one is tensed and drawn up), and in the mouth (open and the lips are drawn back and slightly tensed)[5]. Specifically we focused on whether the children were showing fear on any degree, from apprehension, worry, to fear.

5. FINDINGS

In this section we present a detailed analysis of the process of migration and how it was perceived by the participating

children. First, we will describe one of the cases of migration in detail, so that the reader can picture the scenario followed in this study and form a clearer idea of the reactions that occurred. Second, we will describe the manner in which migrations happened, and the differences that occurred in the transition between embodiments. We will then focus on 'in the moment' details in the migration process and the effect they had on the children's perception of the migrating pet, and their experience and understanding of the migration.

5.1 One example migration

To illustrate the scenario and migration process in this study, we here provide an example of one pair of two girls during their session and their reactions during the migration process.

The pair consists of two girls (C1 and C2), who start their session by interacting with ViPleo. Both PhyPleo and ViPleo are on the table within the girls' sight and at hand; ViPleo is closer to C2, and PhyPleo closer to C1. The scenario is described in Table 1.

After the migration took place, none of the girls interacted with ViPleo (which is turned off) any more, and both focused on PhyPleo from this point on. It is interesting to note that PhyPleo caught both girls' attention before coming to life; although in the case of C2, this appears motivated by the fact that the application in the mobile phone switched off (ViPleo off). As for the reaction of the children regarding the migration, there is no sign of fear in any of the girls.

It is worth noting that C1 did not see ViPleo switching off, and we did not have a good sight of C2's face. We only noted she frowned slightly, but no emotional state can be inferred from this.

When PhyPleo started, both girls reacted in surprise first (quick blink in C2, and C1 withdrawing her hand). However, we do not read fear in these reactions. After this, and still blended with surprise, happiness appeared and started taking over in terms of the main emotional reaction displayed.

5.2 Types of migration

All instances of the migration process were not executed in the exactly same way. Albeit unknown before the study took place, we realized during the video analysis that it takes longer for ViPleo to migrate to PhyPleo than the reverse. When the migration goes from PhyPleo to ViPleo, there is usually a time in which the mobile phone application actually launches and PhyPleo is not still off.

The cause of this may reside in the way the migration is technically implemented. However, informing about the exact reasons and possible solutions lay beyond the scope of this paper. For our study, this unintended difference in the way the migration took place actually yielded interesting results that we are presenting below, and which we believe can inform future implementation of migrating pets.

Besides one single smooth migration and five migrations with technical problems, there were two variations:

a) Gap migrations: there was a gap in between the two functioning embodiments, meaning that the first embodiment would switch off, and it would take some seconds (usually around 4 seconds) until the second embodiment switched on. This migration happened in the direction of migration from ViPleo to PhyPleo.

b) Overlap migrations: there was some time in which the two embodiments were functioning at the same time, until

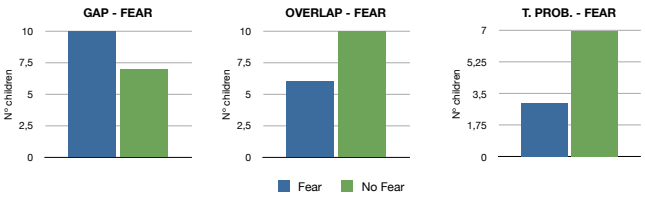

Figure 3: Relationship between fear and type of migration

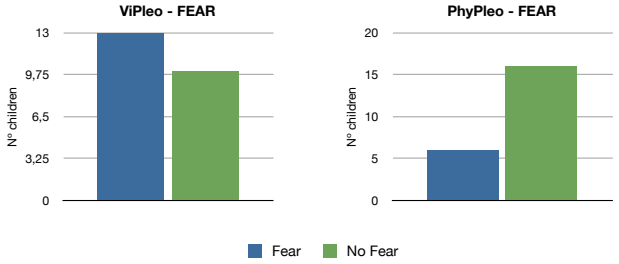

Figure 4: Relationship between fear and type of embodiment

the first one would switch off. This period ranges from 4 seconds to 19 seconds, and includes the presentation of a splash screen (like a video game) in the mobile device. The direction of overlap migrations was always from PhyPleo to ViPleo.

As for the technical problems mentioned before, there were 5 times in which the migration required our assistance, either due to technical problems like the failure of the automatic migration process, or because one of the embodiments run out of battery before the migration. In those cases, we manually performed the migration.

There was yet one session in which the migration protocol was not fulfilled and it was also considered a technical problem: a double migration. In this case, the migration happened twice: from PhyPleo to ViPleo, and then back to PhyPleo.

As for the frequency of each type of migration, there were 17 children who witnessed a gap in their migration (ViPleo to PhyPleo migrations), 16 children who witnessed an overlap migration (PhyPleo to ViPleo migrations), 10 who experienced a technical problem in their migration, and 2 who actually had a smooth migration.

5.3 Number of dinosaurs

As previously reported in [7], just half of the children that participated in the study stated that they had played with a single dinosaur. In this paper, we are taking one further step and try to understand what might have influenced the children's perception of one or two characters, their understanding and mental model of the embodiments, and the differences they perceived between the two of them.

The type of migration appeared to play a role in the children's perception of how many dinosaurs they interacted with.

Twenty four children perceived there was only one character. Of the 24 children, 11 experienced a gap migration, 1

Table 1: One example migration. Pair 8.

C1	C2
Before the migration	
Both girls are interacting with ViPleo, while C2 is taking the lead. Both are leaning into the screen of the mobile phone, and C1 has stood up to have a good view of ViPleo	
Suddenly, C1 checks on PhyPleo (which is still off). She both looks at the robot, and moves herself towards it.	C2 is very focused on ViPleo.
She then turns back to look at ViPleo and resumes interaction.	
After 43 seconds and just after having touched the screen of the mobile phone, C1 stops interacting with ViPleo and starts interacting with robot PhyPleo (while still off).	
During the migration	
Just when C1 has started to interact with PhyPleo, the migration starts, and ViPleo switches off.	Unlike C1 who has focused on PhyPleo, C2 remains watching ViPleo.
However, C1 does not notice as she has her attention focused on PhyPleo (which has not yet switched on), and caresses its snout. C1 appears to quickly peek at the researchers (the two researchers are present - purposely busy talking on our own and looking at each other -) and looks back at PhyPleo	C2 notices the mobile phone switching off immediately, frowns, and remains watching the mobile phone. C2 remains watching ViPleo for about 5 more seconds.
C1 whispers something to PhyPleo	Just as C1has whispered something to PhyPleo, C2 shifts her attention to PhyPleo.
Just in that moment, PhyPleo switches on. Both girls see this event immediately.	
C1 shows a surprised reaction.	C2, surprised too, blinks. She looks over PhyPleo from head to tail.
C1 starts smiling, looking at PhyPleo.	C2 reaches PhyPleo to pet it.
C1 similar mouth than C2, eyes and cheeks happy.	C2 smiles with surprised eyes. She drops her jaw, emits "*Ahhh!*"), and meanwhile pets PhyPleo.
	C2 still has surprised eyes and smiles. Her smile has grown. C2 looks happily at C1, and then back at PhyPleo.
C1 starts petting PhyPleo. Looks happy.	C2 also interacting with PhyPleo and looking happy.

experienced a smooth migration, and 6 had technical problems. Only 6 experienced overlap migrations. Thus a majority of the children who perceived one single character did only see one embodiment at a time. The most common reasons they gave for interacting with one character were similar appearance, actions, and behavior of the two embodiments:
Pair 7, C1: "*Because he had more or less the same shape.*"
Pair 8, C2: "*I think it's because they have the same attitude and reacted the same way*

Fifteen children perceived they had interacted with two characters. Of those, 9 experienced an overlap in the migrations, 4 experienced gap migrations, 1 had technical problems in the migration, and 1 had a smooth migration.

The most common reasons they gave for interacting with two were related to the different capabilities of the two embodiments.
Pair 2, C2: "*[...] because the phone does more things, or at least we can do more things*"
Pair 20, C2: "*one made you company and just ate [...] and the other you could do courses with it, cried and sat.*"

5.4 Emotional reactions to migration

During the sessions, we realized how expressively children reacted to the migration. Many children reacted with surprise when the migration happened, but sometimes we could also see short periods of fear which transformed into happiness or joy. Below we discuss the emotions children expressed in relation to the migration process and the two embodiments.

There were 39 children whose facial reactions were visible to the cameras during the moment of migration (the rest of the cases, the visibility is limited, or they are obstructing their face, or expressiveness was too limited to be reliably categorized). In total, there were 19 cases of fear in various degrees of intensity, i.e apprehension, worry, etc., perceived in the children.

Type of migration and fear

Eight gap migrations occurred (17 children). Ten children of those 17 who witnessed a gap migration showed fear. Six of them did not show any form of fear, and one of them we did not have a clear vision of her face in that moment.

Eight overlap migrations occurred (16 children). Six children of them, witnessed an overlap migration; the rest (10) did not show any form of fear.

Five migrations showed technical problems (10 children). Three children of those 10 showed fear, three of them did not, and for 4 of them their reaction was not visible. In all these cases, there should have been a migration between ViPleo and PhyPleo, but PhyPleo would not start after the mobile phone switched off. The gap is of 30 seconds to one minute, time in which we fixed the problem and the migration happens afterwards.

This suggests that is more likely that children experience fear if there is a gap or technical problems in the migration, compared to smooth migrations, or migrations in which there is an overlap. A possible reason for this is that the gap makes children think that the dinosaur is broken. The relationship between the type of migration and fear is displayed in Figure 3.

Type of embodiment and fear

In 11 sessions ViPleo was the first system to migrate to PhyPleo (23 children). Some sort of fear was seen in 13 children. It is worth noticing that all these cases coincide with gap migrations.

In 11 sessions PhyPleo was the first system (22 children). There was some sort of fear in 6 children, less than half the former case. It is worth mentioning here that these cases coincide with overlap cases.

Also, it seems more likely to experience fear when it is ViPleo the system which freezes, compared to when PhyPleo switches off. The relationship of type of embodiment and fear is displayed in Figure 4.

5.5 Understanding of migration

Video and interview analysis yielded a number of issues regarding the understanding of the migration process. We are highlighting here some of them:

Responsiveness

Responsiveness affects the emotional reaction caused during the migration: some children showed fear when, once the migration had started, they perceived a non-reactive embodiment (we note that awareness is the key here). This means that an embodiment 'off' does not necessarily trigger fear, but the fact that the embodiment does not react to the interaction does. For instance, one pair did not show fear when the mobile phone switched off, but when they attempted to interact with it by touching the screen and the mobile phone did not react, they did show such a reaction.

What is physical is real

During different moments in many interviews, children referred to PhyPleo as "the real" or "the normal", whilst they would refer to ViPleo as "the virtual", "the videogame":

In session 2, when explaining why they didn't count the number of times they fed Pleo the children noted:

C2: *"Because there it is **like a game** (pointing to the phone) [...]. Because **it was virtual** we could not touch him. It was sort of **going to the internet** and play some games"*

In session 23, C1: *"Because we can give him cuddling without being, without mobile phone. And that is more interactive, and it can be, like, like a **real animal**."*

Besides the children's reflections during the interviews, we realized in the video analysis that a couple of pairs actually 'talked to' PhyPleo, like C1 in our example above. Some of them address PhyPleo by talking in the form of *baby talk*. This seems to indicate PhyPleo is open to this kind of 'real interactions', similar to those with babies and pets.

Revive! Mental models 'borrowed' from real life

In the line of the previous comment, one of the participants, during a GAP between PhyPleo and ViPleo, uttered *"Revive!"*, smiling and looking at PhyPleo and emphasizing it with a gesture with his fist. Due to his smile we can assume he was not really worried, but this did indicate his mental model of 'PhyPleo off' corresponding to a 'death'.

Another mental model from 'real life' used to explain PhyPleo switched off mentioned by one pair, was that it was asleep. E.g: In session 7, when asked about migration, a children replied:

C2: *"Maybe it was sleeping (laughter)"*

Three pairs, when explaining the migration, mentioned a change of 'place' or 'scenery', sometimes meaning a difference in the abilities of the character or the number of activities you could do with it. None of them showed fear in the migration. E.g:

Pair 18, C2: *"It was as if, Dino would get out of the virtual to (the) real [...].To the real world. "*

Power of same goals

Some actions/behaviours were described by children as existing in both embodiments, whilst they actually existed in only one of them, i.e. there are two pairs who, when asked why they had perceived only one dinosaur, mentioned the similar behaviour and actions the two embodiments had; they even included actions that were performed by only one embodiment, like 'drinking'. This may indicate children might perceive these actions as a one part of a broader goal of the dinosaur to fulfill its basic needs (food and water). E.g:

Pair 20, C1, motivating why they perceived one dinosaur: *"because they were behaving the same way. [...] (they) ate, drank "*

Double migration

One of the migrations that we have catalogued as a *technical problem* was a double migration: there was a migration from PhyPleo to ViPleo and then, one minute later, a second migration back to PhyPleo.

This 'failure' of the protocol of the experiment actually yielded a very interesting result: the fact that there were two migrations may have given the children more hints about what the migration was. That, joint to the fact that one of the children appeared quite talkative and was thinking aloud, resulted in a theory about the connection between the two embodiments, when asked about the number of dinosaurs:

C2: *"[...] if he (ViPleo) drank, he (PhyPleo) also drank. If he (ViPleo) played, he (PhyPleo) also felt happy to be playing, [...] because the cellphone also connected with that one [...]"*

Responsibility for the migration

Some children, like the ones whose interaction we have described above, felt responsible for the pet migration. There are three cases in which children mentioned this perception of responsibility in triggering it.

The children's perception of control over the migration appears to decrease the number of cases of fear, perhaps because in those cases they have a plausible explanation of the migration. Of the three pairs who reported they believed they caused the migration themselves, none showed fear during the migration, but rather showed surprise instead. E.g:

Pair 11, C1: *"When we touched the cellphone he stopped, right?!"*

Pair 8, C1: *"We were playing on the virtual, and inadvertently did this in the normal and I think he began to move, I think it was then [...]. We were moving and I inadvertently took a touch and he began to move*"

5.6 Quantitative findings

To understand how the migration may affect the children in the perception of the artificial pet and their relationship with it, we compared the answers from the two closed questionnaires, before and after the migration, for each of the test groups. Wilcoxon Signed-Rank tests yielded significant results on three aspects of the interaction:

Migration makes it 'more difficult'?

Results from the questionnaire filled out at the end of the session indicate that the interaction after migration was perceived as more difficult than the first part of the interaction, independently of what embodiment the children interacted with first.

For those who started interacting with PhyPleo first, the difficulty perceived at the end of the session was significantly higher at the end of the session (Mdn = 5) compared to the difficulty perceived before the migration happened (Mdn = 3), $T = 4$, $p < 0.05$, effect size $r = 0.499$, which is considered a medium to large size effect according to Cohen's criteria [2].

For those who started interacting with ViPleo first, the difficulty perceived at the end of the session was significantly higher at the end of the session (Mdn = 4.5) compared to the difficulty perceived before the migration happened (Mdn = 2), $T = 1$, $p < 0.05$, effect size $r = 0.49$, which is considered a medium to large size effect.

Increased understanding of Pleo

After the migration, children reported understanding Dino's feelings significantly better ($p<0.05$).

For those who started interacting with PhyPleo first, 'understanding of Dino's feelings' was rated slightly higher at the end of the session (Mdn = 4, Mean = 3.88) compared to when rated before the migration (Mdn = 4, Mean = 3.46), $T = 5$, $p < 0.05$, effect size $r = 0.295$, which is considered a small to medium size effect.

For those who started interacting with ViPleo first, understanding was rated slightly higher at the end of the session (Mdn = 4, Mean = 4.29) compared to when rated before the migration (Mdn = 4, Mean = 3.92), $T = 1$, $p < 0.05$, effect size $r = 0.360$, which is considered a medium size effect according to Cohen's criteria.

Feeling closer to Pleo

After the migration, the children feel significantly closer to Pleo ($p<0.05$).

For those who started interacting with PhyPleo first, closeness was rated significantly higher (increased closeness) at the end of the session (Mdn = 8) compared to when rated before the migration (Mdn = 7), $T = 2$, $p < 0.05$, effect size $r = 0.367$, which is considered a medium size effect.

For those who started interacting with ViPleo first, closeness was rated significantly higher (increased closeness) at the end of the session (Mdn = 7) compared to when rated before the migration (Mdn = 6.50), $T = 1$, $p < 0.05$, effect size $r = 0.447$, which is considered a medium to large size effect.

Regarding other effects that migration may introduce in play, and balancing the fact that a migrating pet may be more difficult to 'digest' than a robotic or virtual pet, it appears that children increased their understanding of the pet, and felt closer to it, at the end of the sessions. Having had more time interacting with Pleo may have had and effect on these results. However, it seems that migration does not hamper the children's understanding of Pleo nor their relationship to it.

6. DISCUSSION & DESIGN IMPLICATIONS

Looking at the children's emotional reactions, many children were positively surprised when they experienced the migration - a reaction that encourages exploration and continued play. On the other hand, some children experienced fear, anxiety or apprehension, which can produce the opposite reaction. Fine tuning of features to increase understanding of the process, perceptions of control and careful timing of the migration process are particularly important to obtain potential positive effects of migration.

6.1 Understanding and control

The survey data indicated that migration made the participating children perceive the interaction with Pleo as more difficult. During the interviews, it appeared though, that many of the children managed to make sense of the migration even tough they had never experienced it before, and even though the concept purposely was not explained to them beforehand.

The mental models children created as well as their feeling of responsibility over the migration are factors that appear to mitigate potential anxiety. For example, none of the children who in the interview explained the migration as a change of place, or as a result of their own actions, showed any form of fear.

There is a difference of perceived 'realism' in the way the children seemed to have perceived the two embodiments, and the mental models associated with the migration order. For example, some children use the terms 'the real' or 'the normal' to refer to PhyPleo, whilst ViPleo is referred as 'the (video) game'. The mental models associated with the migrating from PhyPleo to ViPleo (PhyPleo turning off) were for example the dinosaur dying, going to sleep, or changing places, whilst the mental model that seem to fit migrating ViPleo (ViPleo turning off) appeared to be borrowed from existing experiences with screens going black, screen savers starting up, or a mobile phone running out of battery.

Also, PhyPleo's reactiveness is more visible than ViPleo's. When PhyPleo stops working, it stops moving and making noises, which is usually noticed by the children right away. Unlike with PhyPleo, the reactiveness of ViPleo is more subtle. The screen going black is less eye-catching than PhyPleo stop moving, even more if the children are busy in secondary tasks like writing down whether Dino has just eaten.

Awareness and understanding of the process can mitigate negative reactions. It would be helpful to give more control to the children over the migration since those who believed they were responsible for the migration did not show fear. Since it might be difficult to exactly control the migration, children might benefit from support illustrating the process, as suggested in [11].

Additional support for understanding the migration could include 'rituals' or familiar, comfortable mental models such as falling asleep, and would help to overcome perceptions of 'death' of an agent or worries when an embodiment ceases to be active, (perhaps inspiration could even be taken from SciFi movies such as Avatar and the Matrix in which a protocol must be followed by the character to 'cross to the other world'). Perceptions of control, and less sudden transitions rather than simply 'freezing' an embodiment could potentially help.

6.2 Type of embodiment and migration order

Considering the different models used for the different embodiments, and the difference in realism associated with PhyPleo and ViPleo, it would seem as if the migration between PhyPleo and ViPleo could be more problematic than the reverse, as the 'real' Pleo could be seen as 'dying'. However, as we have seen in the section about emotional reactions to migration, fear is mostly seen when the direction of the migration goes from ViPleo to PhyPleo. A plausible explanation is that most of the cases in which fear was seen, there was a gap in the migration.

This points to a notion that the type of migration has more weight in the children's reaction to the migration than the direction of the migration.

Our study revealed a tension in how to design migration for children: an overlap in the migration makes it difficult to see it as one character with two embodiments, while a long gap can be scary. Timing was important for how the character was perceived. A too long gap made most of the children perceive one character, while an overlap made most of them perceive two, which seems a plausible consequence of having perceived two Pleos active at a time (in overlap migrations), or just one (in migration with gaps or technical problems). In order to maintain the experience of one character migrating between two embodiments, it is important that only one is active at a time - synchronization and timing can play a decisive role.

In our case, a smooth transition between embodiments occurred only rarely. While sceptics may point out that this is up for improvement, the issues occurring here do serve as stark reminder that interaction with migrating agents and the migration process are very unlikely to be 'ideal' every time. Technical issues can occur, communications between embodiments can break down, gaps and overlaps may happen. Therefore careful consideration is not only required for the design of the embodiments, the persistence and consistency of the agent, and embodiment-specific behaviours, but also especially the manner in which the transition occurs between them.

Responsiveness and interactivity of the embodiment as well as perceived control over the migration helped children to understand the migration. This can be incorporated in the design of the migration, for example by making sure that the target embodiment is at least active, ready, and waiting for the migration. One way of assuring this could be to start it up before the other embodiment 'goes to sleep'. Again, graphics or other support that illustrates the process of migration could help the children understand why an embodiment is not responding and tell them when it will come back 'alive'.

6.3 Future work

We need to take into account that our results are based on 10-11 year old children's first encounter with migration. It is likely that their reactions and understanding would change over time as they got more familiar with the concept.

Future work on migration as a support for play and interaction between children and robotic toys primarily include trials where children experience a number of migrations to explore how they experience and understand the concept when given more time.

Here, children were not used to migrating characters and they only experienced a single migration which often provoked emotional reactions such as fear or surprise. If expe-

riencing a series of migrations, children would become more familiar with the concept and react differently.

However, when designing for children the first impression is important. If the first experience was unpleasant, children would be less likely to continue playing with the migrating Pleo and build up an understanding of the migration.

Last, and regarding the design of PhyPleo and ViPleo, and judging from how the children explained their perception of one or two characters, it appears that the designed behaviours for needs and goals created both support for a single character and two different ones: some of the children reported to have played with one single dinosaur since both embodiments behaved in the same way, while other children reported there were two since they behaved differently.

We cannot say whether there were differences in how the pairs interacted with the embodiments and therefore saw different behaviours, or if it is just personal differences in how the behavior and functionality added to each embodiment was understood and interpreted. It does suggest, though, that extra care is needed when designing different behaviours that take advantage of the possibilities that different embodiments have.

7. CONCLUSION

Migration of characters from one embodiment to another can provide a number of benefits in terms of adaptation to tasks and context, mobility and maintenance, as well as long-term engagement with users. Designing such migrations and their implementation, however, are by no means straightforward affairs.

In this paper we have explored the process of migration and some factors that led 10-11 year old children to perceive a persistent identity of a character toy that migrates from one embodiment to another.

In our case, we look at interactions with a robot dinosaur which can be embodied in two different forms and which can migrate from one to the other. A number of challenges come hand in hand with designing for such interactions, like believability of the agent, the perception of one or more than one character, and fear associated with a misunderstanding of the process of migration.

Our results show that the manner in which the migration is designed, actually occurs, and is experienced, affects the perception of one single character. Variations and seemingly subtle differences in the migration process can affect users' perspective on the agent and its embodiments. Gaps in the migration process, and perceived unresponsiveness for example, appeared to be accompanied by anxiety in the participating children. Implementing a smooth migration process is challenging, and technical breakdowns are likely to occur.

We need to understand how these affect users' perceptions of the agent and its embodiments, and we need to pro-actively design for such occurrences in a manner that avoids anxiety and uneasiness. This would allow for reaping migration benefits, while avoiding interaction breakdowns.

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