Comparing Ways to Trigger Migration between a Robot and a Virtually Embodied Character

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Abstract. The question of whether to use a robot or a virtually-embodied character for applications in need of a socially intelligent agent depends on the requirements of the task at hand. To overcome limitations of both types of embodiment and benefit from advantages provided by both, we can complement a physical robot with a virtual counterpart. In order to link the two embodiments such that users perceive they are interacting with the same entity, the concept of "migration" from one embodiment to the other needs to be addressed. In this work, we investigate a particular aspect of this concept, namely how to best perform the triggering of migration, within the context of a physical activity motivation scenario for adolescents. We design two methods, a proximity-based method and a control, and compare their effects on adolescents' perceptions of our agent. Results show that users perceive the agent as more of a friend and more socially present in the proximity-based than in the control condition. This emphasizes the importance of investigating different facets of entity migration for systems in need of employing both a physical and virtual embodiment for an artificial agent.

1 Introduction

The field of Human-Robot Interaction (HRI) has highlighted the importance of a physical embodiment in contexts where we wish to use an artificial agent to provide supportive behaviors to a person. Research shows that having a physically embodied agent (as opposed to a virtually embodied one) has significant positive effects such as increased compliance [5], better learning gains [17], improved social facilitation [6], and higher perceived social presence [25]. However, physical robots still present a variety of problems, such as limited battery life, need for mechanical maintenance, wear and tear, and physical limitations in the range of behaviors displayed. Such problems are particularly significant for robots intended as social companions since they are expected to be constantly present and available for interaction. Virtual embodiments are more robust, allow more complex interaction design and greater portability. An agent that can co-exist across multiple embodiments can be helpful in obtaining the benefits of both types of embodiment and mitigating their individual disadvantages.

Entity migration is defined as "the process by which an agent moves between embodiments" [11]. This concept has been studied in Human-Computer Interaction and HRI as an important paradigm allowing for the extension of a particular embodiment's abilities and limits. Migration has a huge potential to benefit applications seeking to employ social companions providing assistance to people in a multitude of domains, such as supervision, companionship, coaching, motivation, and so on. This is due to the fact that each application has its own requirements for the length, duration, frequency, and form of interactions. Switching between a physical and virtual embodiment can greatly help meet the necessities dictated by the task at hand at any point during the interaction.

We present an investigation into entity migration within the context of a robot companion whose long-term intended purpose is to keep adolescents motivated to engage in daily physical activity. Such an application domain for robot companions (especially relevant to adolescents, for whom physical activity plays a key role in healthy growth and development [8] and who show severely low adherence to physical activity levels recommended by health guidelines [1]) stands to fully benefit from employing entity migration. Thus, providing constant support necessary for behavior change [19] can be achieved through continual access to a virtual embodiment, while employing persuasive strategies necessary for motivation [12] would gain from temporarily switching to a physical embodiment. We argue that the way in which we perform migration from one embodiment to the other can engender different perceptions of the agent in users, providing a valuable tool for achieving more positive perceptions.

We thus explore the effects of the triggering phase of migration on users' friendship and social presence perceptions of the agent. Such perceptions are important for the supportive behaviors provided by our agent to be effective in a future-intended long-term deployment. These perceptions can be used to leverage humans' tendency to develop social relationships with the objects they interact with, tendency that is especially strong with respect to biological and artificial agents. Leveraging this tendency is important in guiding users towards perceiving the robot companion as more than a mere tool, rather as a social and persuasive agent (capable of changing their attitudes, behaviors, or opinions) [9].

In this paper, we develop a proximity-based method of performing migration triggering (a more novel, sensor-based approach) and a control method (a button-based approach). We test the effects of our migration triggering methods during a single-session study centered around our physical activity motivation scenario. We hypothesize that:

H1: Users will perceive the agent as more of a friend in the proximity-based condition (PBC) than in the control condition (CC).

H2: Users will perceive the agent as more socially present in the PBC than in the CC.

Our results support both H1 and H2, revealing that we can effect stronger friendship and social presence perceptions via migration triggering methods that rely on more innovative approaches. This suggests that exploring different migration aspects has the potential of bolstering postive rapport building in HRI.

2 Related Work

One of the first projects investigating the concept of "migration" was The Agent Chameleon Project [10]. This work addressed research questions including agent identity [21], migration architecture design [10], and agent change of form based on deliberative reasoning [20]. Other projects have investigated how to implement migration between two robots [3], how to implement migration of multiple companions who share the same embodiment [2], whether migrating the memory of the agent would affect users' perception of consistent agent identity [4], and higher engagement of children with blended reality characters [26]. The current paper investigates the triggering phase of migration and its effects on users' perceptions of the robot, an aspect of migration not present in this body of work.

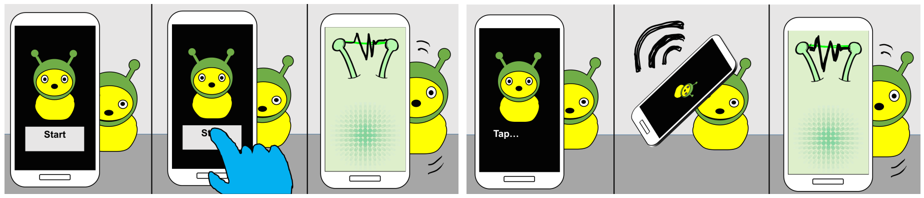
In a study designed to construct an emotional relationship between humans and interactive systems, participants' tendency to "help" an agent is higher when the agent first migrates into a physical robot than when it remains in a virtual avatar displayed on a laptop [23]. This study indicates the relevance of using a physical embodiment to establishing a positive emotional relationship. The enhancement of user-agent relationship is also stressed in a study in which participants interact with a personal agent on a mobile PC that migrates to a physical robot guiding them on a tour [14]. The system is designed to support the user gaining familiarity with the personal agent, but no aspects about users' perceptions of the agent are discussed. Finally, a study in which children interact with an artificial pet dinosaur that migrates between a virtual avatar on a smartphone and a physical embodiment finds that close to half of the participants perceive the two embodiments as corresponding to the same entity [11].

Our work investigates an aspect that, to the best of our knowledge, has not been previously explored in migration literature. The studies presented here do not tackle the triggering of migration and they either do not specify exactly how this is performed or they trigger migration through a button-based approach [11]. In this paper, we focus on how changes in the triggering phase can affect how strongly users perceive the agent as a friend and as a socially present party in the interaction. Perceptions of friendship and social presence engendered by migration triggering also constitute a research direction that has not yet been investigated in this literature and represent an important step for gaining insights into how we can leverage migration to effect more positive perceptions of agents.

3 Methodology

3.1 Application Scenario

Our study centers around the application scenario of a robot companion motivating adolescents to engage in daily physical activity. We present here a single-session study, representing the first interaction of the intended long-term deployment. The current study consists of the robot walking users through its back-story, while explaining the different motivational strategies it would employ during the longer study. The agent has the back-story of a "robot-alien"



(a) Control condition (b) Proximity-based condition

Fig. 1: Interaction design showing the agent's physical and virtual embodiments.

whose space ship broke down on Earth, and needs to gain "energy points" for repairing its ship and returning home. By exercising routinely, the user can transfer points to the robot. The transfer is mediated through a wristband device (which the robot can connect to) provided to users during the intended long-term deployment, measuring their daily physical activity level.

During the intended long-term study, the agent can employ four motivational strategies: cooperative persuasion, competitive persuasion, conveying information about physical activity via lessons and quizzes, and promoting self-reflection [12]. We sustain these strategies by providing users with a smartphone they can carry with them constantly, including when they do not have access to the physical robot. Participants also use the device during their short, daily interactions with the physically-embodied robot to communicate with it.

3.2 Forms of Embodiment

Physical. This embodiment is based on the Keepon robot, a non-mobile platform with four degrees of freedom [15]. We use a commercially available version named MyKeepon, modified to make programmable. This is a robust and simple platform allowing for a potential long-term use of our agent. This embodiment allows for a straightforward design of our 2-D virtual avatar as the robot has salient features that can be intuitively replicated, i.e. its shape and color. The green hat with the antennae add-on is reminiscent of an alien and is used to complement the agent's "robot-alien" back-story, as seen in Figure 1.

Virtual. This embodiment consists of a 2-D avatar with similar visual appearance to Keepon (so that users perceive they are interacting with the same entity across conditions). We display this avatar as part of an application installed on a smartphone that helps the user communicate with the agent. The application consists of an interface showing the avatar. When the user performs the migration triggering action, the interface changes to display a set of antennae (reminiscent of the physical robot's hat) with a signal crossing between them. This animation always appears when the agent is talking, as suggested by the signal crossing between the two antennae. This sequence is depicted in Figure 1.

3.3 Migration Triggering Methods

Control condition (CC). This condition is depicted in Figure 1 (a) and represents a basic, button-based approach of performing migration. This method consists of the initial screen showing an image of the avatar together with a "Start" button beneath it, as can be observed in the first sub-image. The second sub-image highlights the action the user needs to accomplish to trigger the migration, namely pressing the button displayed under the virtual avatar. When the user does so, the avatar disappears from the screen with a fade-off animation and the physical robot wakes up and starts talking.

Proximity-based condition (PBC). This condition is depicted in Figure 1 (b) and represents our sensor-based approach. For this method, we use Near Field Communication (NFC). NFC is a technology that enables a device to communicate with another at a maximum distance of around 20 cm, and is widely used in commercially available smartphones. Triggering migration via NFC allows users to employ devices they are already familiar with for communicating with artificial agents. NFC has been used in gaming applications [18], but to our knowledge has not been previously employed in the context of HRI for migration.

We place the NFC tag on top of the robot's head, under its hat. Users see a similar initial screen as in the CC showing an image of the avatar, with a message underneath reading the text "Tap the robot's head with the back of the phone". When the user does so, the phone vibrates once and the avatar disappears by displaying a swirling away animation and sound. This is represented in the second sub-image. The physical robot then displays the same "waking up" animation as in the CC and the interaction proceeds in the same manner thereafter. We decided to use a vibration effect when touching the robot. This is common in NFC-based applications as it gives users additional feedback that an action was triggered, something that is clear when pressing a button. We chose to change the animation from fade-off to twirling such that the agent seems to be disappearing into the robot's head. We did so to maximize the visualization of the PBC.

3.4 Participants

We conducted a study in local schools in Connecticut, USA. The study population consisted of early adolescents and adolescents aged 13-to-15, with an average age of 14. Participants were recruited with the help of the school staff and did not receive monetary compensation. The study consisted of $n = 26$ participants, 14 female and 12 male.

3.5 Procedure

We assigned participants randomly to one of our two conditions. We employed the CC for 13 participants and the PBC for the other 13. Each participant was given an assent form to read and sign prior to taking part. The participant was then seated at a table where the physical robot was already present yet still and silent. A researcher started by giving a brief overview of the project so that the participant would be aware of the physical activity motivation scenario.

Participants were not instructed on how to use the system, rather they were provided with a smartphone presenting a screen with our virtual avatar. The

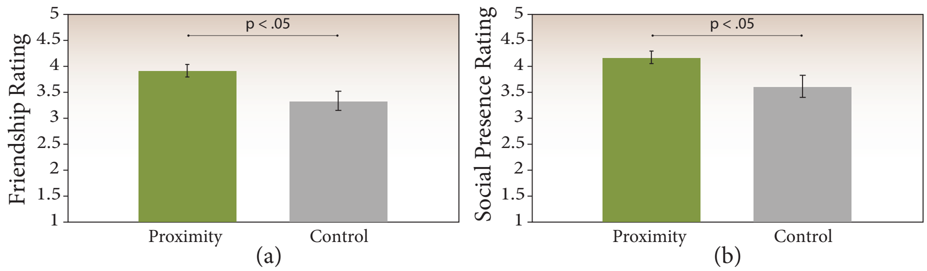


Fig. 2: Participant ratings for the (a) friendship scale, (b) social presence scale. Error bars represent $\pm 1SE$.

screen presented different instructions based on the triggering migration group participants were assigned to, with explanations to proceed. In the CC, participants saw a button labeled with the text "Start" underneath the virtual avatar, whereas in the PBC, participants read the text "Tap the robot's head with the back of the phone" displayed underneath the virtual avatar.

The interaction proceeded as follows. Users were able to initiate the migration process from the virtual avatar to the physical robot at any point, as explained by the instructions for each condition. The migration occurred as described in subsection 3.3. After the process was complete, participants interacted with the agent by using our custom dialogue interface. During this part, users were introduced to the story line of our scenario, as the agent talked about the importance of physical activity and different motivational strategies it would employ in a long-term scenario. An example of something the robot said is "On my home planet, we know a lot about physical activity", linking elements of its back-story to the physical activity topic. The agent asked six questions as part of the dialogue, and participants could choose between three simple entries to answer. We used the Google Speech Recognition API to allow users to verbally respond with one of three simple answer choices displayed on the smartphone. The different choices slightly affected the robot's responses so that participants were assured that the robot understood their answers. The script was otherwise fixed and straightforward. Overall, the interaction lasted approximately seven minutes.

After the interaction with the agent, participants filled out two questionnaires, and were interviewed by a researcher on the migration aspect they had just experienced.

3.6 Measures

During our study, we gathered both quantitative and qualitative data. First, we collected questionnaire data in the form of one-to-five Likert scales for both friendship and social presence. Second, we simultaneously recorded and wrote succinct transcriptions of users' answers to interview questions about migration.

Friendship. This measure indicates the perceived fulfillment of the functions of a friendship relationship as provided by our agent. Although friendship perceptions form over time, this measure has been used successfully in HRI to anticipate a robot companion's success for long-term interactions [16]. We believe that it is fundamental to engender the existence of such elements during interactions with social agents. These factors are key to creating positive impressions of the agent, which is especially important during initial rapport development in relationships [28]. Such perceptions increase the likelihood of building positive rapport with our agent, making it more likely to successfully motivate our users. We utilize the short version of the McGill Friendship Questionnaire (MFQ) [22], comprising 30 items in total and six subscales: stimulating companionship, help, intimacy, reliable alliance, self-validation, and emotional security.

Social Presence. This measure indicates the strength of a social agent's presence during an interaction. Succinctly, social presence is defined as "the sense of being with another" [7], and makes for engaging and compelling interactions. This is of immediate relevance for developing robots that strive to interact with their users in a convincing and social way. This measure has also been used successfully in HRI to create believable and enjoyable social robots [24]. Within our physical activity context that relies on employing motivational strategies, a strongly socially present agent would present an even more significant advantage, that of being more persuasive. This insight is based on findings that an agent is more effective at persuasion when perceived as socially present [27]. We used a short version of the standard social presence questionnaire [13], comprising 12 items in total and six subscales: co-presence, attentional allocation, perceived message understanding, perceived affective understanding, perceived affective interdependence, perceived behavioral interdependence.

4 Results

This section presents our study findings and reports on both questionnaire and interview data.

Friendship Perceptions. We evaluated the internal consistency of the complete friendship scale of 30 items (highly reliable, Cronbach's $\alpha = .947$), as well as that of the six subscales (reliable and highly reliable values for each). We thus computed the score for the complete scale by averaging over all values, and scores for each of the six subscales by averaging over values within each. The Shapiro-Wilk test of normality suggested that normality of data was a reasonable assumption ($S - W = .97, df = 26, p = .707$), and so we employed an independent-samples t-test to compare friendship ratings between conditions.

Comparing the ratings for the agent between the two conditions yielded significant results for the complete friendship scale. Figure 2 (a) shows participants rated the agent significantly higher in the PBC ($M = 3.89, SD = 0.47$) than in the CC ($M = 3.35, SD = 0.74$), $t(24) = 2.24, p = .034$. This supports hypothesis H1 and emphasizes the effect of migration on how well users are able to relate with a social agent. Below we look at the data more in-depth.

Given that we had a total of six subscales for each questionnaire, we performed the independent sample t-test using a Bonferroni-adjusted α level of .008 (.05/6) for significance. Our data yielded significant results for the intimacy subscale, with users rating the agent significantly higher in the PBC ($M =$

$3.63, SD = 0.58$) than in the CC ($M = 2.46, SD = 0.33$), $t(24) = 3.18, p = .005$ (t-value reported for unequal variances).

Social Presence Perceptions. We analyzed the social presence data in a similar way to the friendship data. We obtained highly reliable internal consistency for the complete scale (Cronbach's $\alpha = .874$), and reliable and highly reliable values for each of the six subscales. Scores for the complete scale and the subscales were computed in a similar fasion to the friendship scores. The Shapiro-Wilk test again suggested that normality of data was a reasonable assumption ($S - W = .97, df = 26, p = .560$), and so we employed an independent-samples t-test to compare social presence ratings between conditions.

Comparing the ratings for the agent between the two conditions yielded significant results for the complete scale. Figure 2 (b) highlights significantly higher ratings in the PBC ($M = 4.15, SD = 0.49$) than in the CC ($M = 3.60, SD = 0.81$), $t(24) = 2.08, p = .049$. This finding validates hypothesis H2 and supports the importance of investigating how migration effects social presence perceptions when creating an agent intended to engage with its users in a compelling way.

Interview Data. Alongside investigating the effects of migration triggering on users' friendship and social presence perceptions of the agent, we also conducted participant interviews. Our goal was to gauge the impressions users had on the migration process, as well as whether they perceived having interacted with a single entity across conditions. Perceptions of interaction with a single entity are useful when employing migration in order to preserve the acquired positive rapport with the same agent (as perceived by users).

We asked users a range of questions including what they thought was happening when the avatar would disappear from the smartphone and the physical robot started to move, what they felt was being transferred between the two embodiments, and when they felt this transfer was happening. Based on the interview transcriptions, we grouped the answers in themes to gain a better understanding of whether users truly understood the concept of a single "entity" moving between the two embodiments. The main themes we obtained regarding how the agent was described are: "entity," "energy source," "soul," and "spirit." Two interesting examples of responses include "I thought it was a spirit or an energy source because it was talking about inhabiting" and "The robot is a vessel for the entity." These answers show users' understanding that they were interacting with a single agent capable of migrating between different embodiments.

We also asked users the following question: "Did you think that the character in the mobile phone and the yellow robot in the physical world were the same entity?". This question was asked of all participants, regardless of the migration triggering group they were in. An overwhelming majority, 23 out of 26, of participants perceived they had interacted with a single entity during the study. When looking at the groups individually, we obtained the same results. 11 out of 13 participants in the CC and 12 out of 13 in the PBC said they perceived having interacted with a single entity.

Another finding from the interview data was the positive reaction to the migration aspect in terms of its perceived benefits. One participant noted "It is easier to carry around the phone than the actual robot," realizing how useful employing this technique would be in a long-term scenario such as the intended context of use for our robot companion.

5 Discussion and Conclusions

We have investigated entity migration between a physically- and virtually-embodied agent as an important paradigm for contexts requiring us to leverage advantages of both types of embodiment. Within our application context of physical activity motivation, we investigated how changes in the triggering phase of migration affect users' friendship and social presence perceptions of the agent.

Our study reveals that participants rated the social agent significantly higher in the PBC than the CC for both friendship (H1) and social presence (H2). For the friendship measure in particular, we obtained a statistically significant difference for the intimacy subscale, with users rating the agent higher in terms of intimacy in the PBC than in the CC. Our PBC employed a more physical trigger for migration through the use of an NFC sensor requiring a more direct type of interaction. We speculate that for friendship, this trigger effected a more personal type of interaction causing users' perceptions of intimacy toward our agent to increase. For social presence, the proximity required by the method seems to have increased the feeling of "being with the agent", and thus engendered higher perceptions overall. These results show that we can use different aspects of the migration process to our advantage in order to engender higher perceptions of agents, which play an important role in building positive user-agent rapport. Exploring the various nuances of entity migration is thus an avenue well worth pursuing within the context of creating robot companions for application domains such as health, education, coaching, and beyond.

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