

# Virtual Objects in the Physical World: Relatedness and Psychological Ownership in Augmented Reality

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## ABSTRACT

As technology advances, people increasingly interact with virtual objects in settings such as augmented reality (AR) where the virtual layer is superimposed on top of the physical world. Similarly to interactions with physical objects, users may assign virtual objects with value, experience a sense of relatedness, and develop psychological ownership over these objects. The objective of this study is to understand how AR's unique characteristics influences the emergence of meaning and ownership perceptions amongst users. We conducted a study of users' interactions with a virtual dog over a three-week period, comparing AR and fully virtual settings. Our findings show that engagement with the application is a key determinant of the relation users develop with virtual objects. However, the effect of the background layer—whether physical or virtual—dominates the development of relatedness and ownership feelings, highlighting the importance of the “real” physical layer in shaping users' perceptions.

## CCS CONCEPTS

• Human-centered computing • Human computer interaction (HCI) • Empirical studies in HCI

**KEYWORDS:** Augmented Reality, Ownership, Relatedness, Material Culture, Virtual Possessions, Qualitative Analysis

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## 1 INTRODUCTION

Our life is largely defined in terms of the world of objects that we create and possess [1]. We understand ourselves through our relationships with material and immaterial objects [8]. As a result, we have come to develop feelings of ownership over objects, and such perceptions of ownership play a major role in regulating our relationships with other people who may be sharing the interaction space. For example, in a traditional physical setting, we do not take others' possessions without asking the owner's permission. Thus, the way in which people relate to objects - both material and immaterial - facilitates the development of a common understanding over shared spaces.

People's relationships with objects go beyond the use-related utilitarian function of our possessions, and we often develop feelings of symbolic value and emotional relatedness towards objects [20,43]. As a result, the real economic value of objects and their personal value to us are often misaligned, such that people may give greater weight to the personal meaning of their object, beyond its instrumental worth [68].

With the development of communication and graphics rendering technologies, interconnected and visually realistic virtual spaces, such as online games, virtual worlds, and social networks now have a ubiquitous role in our lives. The economy of today's digital applications often resembles its real-life counterparts [27], and users' understanding of the material culture that guides them in the physical world translates into these online simulated spaces [38]. For example, virtual objects in these environments can be bought and sold, stored and gifted, earned and destroyed, and the motivation for engaging with these ephemeral objects is strikingly similar to people's interactions with physical objects [26,45]. In North America alone, massively multiplayer online environments generated the revenue of 1.9 billion USD on in-game purchases<sup>1</sup>, and over the past

<sup>1</sup> <https://tinyurl.com/yaxgfkgu>

year, 69 percent of all players of one of the most popular current multiplayer game “Fortnite” purchased in-game items, with the average per spending player at 85 USD<sup>2</sup>.

The feeling of attachment and the value that people assign to their virtual possessions is sometimes on par with the value that they assign to their physical belongings. For example, a destruction of a virtual item led a user in South Korea to file a lawsuit against the developers of the virtual world<sup>3</sup>. Augmented Reality (AR) technologies enable superimposing virtual objects onto physical environments [5,23]. In AR, the virtual object is presented as if it is a part of the physical world, and users can often interact with it – moving or manipulating it relative to the physical environment (e.g. placing a virtual object on top of a physical object). In such conditions, the users’ relation and perception of the virtual objects may be stronger than with screen-based objects that are disassociated from a physical environment, leading them to experience a stronger emotional relatedness and feeling of ownership over them. A recent study [55] pointed to users’ perceptions of ownership as a central issue in the regulation of interactions in shared AR spaces.

To date, research on the psychological and social aspects of AR is relatively scarce. We maintain that these factors are essential for designers of virtual spaces. The objective of our research is, thus, to increase our understanding of the psychological mechanisms that govern interactions in virtual settings. In particular, we are interested in the way in which users develop the feeling of relatedness and ownership towards virtual objects. This study adopts the theoretical lens of material culture and the psychology of possessions and seeks to develop a conceptualization of meaning and ownership over virtual objects in AR. To that end, we conducted an explorative study in which 20 participants cared for a virtual dog over a three-week period. Half of the participants interacted with a virtual dog superimposed onto the physical reality in AR using the camera of their mobile device. The other half had the dog displayed on the screen of their phone, lacking the grounding of a physical background. We used questionnaires and semi-structured interviews to capture participants’ perceptions of the experience, employing thematic analysis to analyze the interviews. In addition, we conducted a complementary small-scale quantitative analysis of participants’ perceptions. Beyond the expected effects of engagement levels, our findings highlight key differences in perception of the virtual dog between those

who interacted with it in AR mode and those in a traditional fully-virtual 2D mode.

## 2 RELATED WORK

### 2.1 The Role of Relatedness and Enjoyment in our Relationships with Physical and Virtual Objects

Previous research identified several psychological mechanisms that shape the relationships between an individual and her possessions. In particular, we value and cherish our things because we experience emotional connection to them [19] - the feeling of relatedness. Relatedness is an intrinsically motivating source of action [16] and is defined as the desire to interact, be connected to, and experience caring. One of the sources of this connection is the ability of the objects to become a part of who we are and express our identity to others [15,20].

Visceral properties of the objects, such as aesthetics and the ability to provide enjoyment, also contribute to the development of the relationships with our possessions [70]. Studies on material culture discovered that even explicitly utilitarian objects (such as clothes, appliances, or vehicles) are mostly cherished due to their visceral and emotional qualities, rather than their utilitarian purpose (e.g. [68]). Similarly, research on human-robot interaction emphasize the important role of enjoyment and relatedness when interacting with physical technological objects [40]. Enjoyment and the need to belong were shown to be significant predictors of perceived usefulness and ease of use of the service robots [49]. Users were found to infer and relate to the robots’ “social” and “personal” characteristics [36].

HCI research confirms that the feeling of enjoyment and relatedness are among the primary needs that regulate the activity of users in virtual spaces [33]. For example, users interact on social network sites to establish and maintain relationships [33,34,59] and to experience the sense of community [14]. Enjoyment and relatedness to virtual environments and to the objects within them are among the main reasons that drive the users to acquire and engage with items in virtual worlds [12,50,63] and multiplayer games [37]. Finally, visual design is one of the primary factors that determines the participation in virtual environments. Visual appeal influences the perception of object as usable and the more aesthetically pleasing is an object, the stronger feeling of ownership it may foster [37].

### 2.2 The Role of Psychological Ownership in our Relationships with Physical and Virtual Objects

Psychological ownership is defined as a state in which an individual feels as though the target of ownership is theirs (i.e. “it is MINE”) [21,53]. Thus, the experience of possession

<sup>2</sup> <https://tinyurl.com/yc68lnen>

<sup>3</sup> <https://tinyurl.com/yc787sa3>

comprises the core of the psychological ownership feeling [4]. Additional dimensions of psychological ownership - territoriality and responsibility - were explored in different fields, and in a variety of social contexts, including the psychology of possessions, HCI, and informational science.

Territoriality is expressed by both the individual's intention to protect and the protective behavior itself towards the target object or entity perceived as belonging to them, and by the tendency to defend or restrict access to the target from others, perceived as an out-group [46,58]. Territoriality also reflects personalization or marking the object to communicate ownership [32]. Responsibility for the target object or entity is expressed as both as a feeling of responsibility for the continued existence and well-being of the target of ownership, as well as perceiving the explicit privileges and liabilities associated with that target [4,54].

The research community recognized that psychological ownership emerges in users towards digital content [13], informational systems [48], and virtual environments and artifacts [37]. Strong experience of possession over a digital place, object, or information leads to the users investing themselves more into the development of the cyberspace, and spending more time actively engaged in online activities [13,35,56]. Possession and responsibility also increase the perceived usefulness and perceived ease of use of informational systems [7,48]. The feeling of territoriality was found to regulate the interactions of the users in collaborative working environments [62] and virtual reality social spaces [71].

### 2.3 Relationships with Virtual Artifacts in AR

Our relationship with virtual possessions is inherently affective. The experiences of relatedness, enjoyment, and psychological ownership play an important role in the meaning we assign to virtual possessions. Because of its direct relationship with physical reality, AR has even more power than traditional virtual environments to elicit affective reactions [2,47,67]. However, prior studies on the relatedness, enjoyment, and ownership in the virtual context focused primarily on fully-virtual environments. The AR setting has been largely neglected in this respect.

Poretski et al., [55] provided preliminary evidence that social tensions may arise around the ownership of the physical anchors to which the virtual artifacts are attached in AR environments. However, to the best of our knowledge, no studies directly explored how psychological ownership and other relevant psychological aspects emerge in our relationships with the virtual artifacts themselves. Some relevant discoveries exist in the field of marketing. For example, consumers pay special attention to the features of the object that convey that it is genuine, real, or

true - the authenticity of the object [10]. The mere suggestion that the object can be touched increases the perception of realism of the virtual object [30] and increases the perceived psychological ownership of it [52]. AR, by making the object a visible part of the physical reality, may strengthen the perception of the object's tangibility. This may directly contribute to the development of relatedness, enjoyment, and psychological ownership.

In addition, AR was previously found to increase users' engagement [31], which can be defined in terms of the amount of time devoted to the activity [24,61]. The major factors that increase user engagement are types of interaction [66], overall interactivity and diversity of the experience [3,29], aesthetics [51], and immersion [17]. By incorporating the real environment into the overall experience, AR can activate all of the factors above and lead to an increased emotional experience of the users.

To fill the gap in the current understanding of human-object relations in AR, we aim to answer the following research questions:

- RQ1: Does AR increase the experiences of enjoyment, relatedness, and psychological ownership to a virtual artifact compared to a traditional virtual environment?
- RQ2: What other factors contribute to the development of the experiences of enjoyment, relatedness, and psychological ownership in AR?

## 3 METHODOLOGY

### 3.1 Study Setup

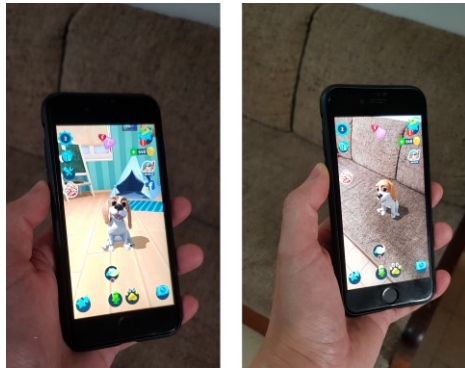
We used a commercial AR application that was distributed as a free-to-play app with the ability to purchase additional items within the in-game store. The application enabled creating and interacting with a virtual dog (similar to the well-known Tamagotchi game). Using the application, the users were able to create, name, feed, clean up, dress, and customize their dog. They could also teach the dog voice commands using the built-in microphone and interact with it verbally.

The dog's behavior and needs resembled those of a real dog: it needed to be fed and played with, the owner was required to clean after it, it could be in a happy, fair, or sad mood that was reflected in its appearance, expressions, and behavior. If the owner neglected to tend for the dog for two days, it was taken from her and disappeared from the app. In addition, the dog grew over time, changing its appearance from a puppy to an adult animal. The dog was represented as an animated 3D model object (see Figures 1a and 1b). However, the application allowed two different modes of viewing and interacting with the dog:

- **VE mode:** Conventional rendering of a simulated 3D dog on the screen of the mobile phone. In this mode,

the user sees the dog inside a virtual room on the screen. We define this mode as Virtual Environment (VE) (see Figure 1a).

- **AR mode:** The application superimposes the dog onto a physical location of the user (e.g. living room) using the phone’s camera. The user is able to see the dog by viewing the environment through the phone’s screen. The dog “resides” in the location the user places it in. It is possible for the user to move the dog around and “place” it in other locations (see Figure 1b).



**Figure 1a and 1b: The view of the application with the virtual dog represented in VE mode (left) and AR mode (right).**

It is important to note that the graphical model of the dog, its look and features, its behavior, and all functionality within the app were identical across modes. The only difference in the user experience was the setting AR or VE.

In addition to the core experience, the application included some complementary gamification elements. There were few simple games that one can play while being in the application. Playing these games allowed the user to earn the in-game currency - “coins” that could be spent on buying optional new toys, items of clothing and food for the dog. These actions advanced the level of the users granting them achievements badges.

### 3.2 Procedure

During the study, we met with the participants two times - first at the introductory session at the start of the study, and then three weeks after at the interview session. In the introductory session, we first described the details of the study, after which we administered a number of questionnaires including demographic characteristics, AR proficiency, and territoriality disposition. Upon completion of the questionnaires, we randomly assigned the participants to one of the two groups: AR or VE, depending on the mode in which we required the participant to

interact with the dog. The participants were not allowed to switch the mode of interaction during the study period.

The participants were required to bring their own mobile phones to the introductory session. Only participants with iPhone models 7 and 8 (which have identical screen sizes and similar AR capabilities) participated in the experiment. We installed the application on their mobile device and created the virtual dog in it. The participants were instructed to take care of the dog at home for a period of three weeks. We guided the users through the functionalities of the app, demonstrated how to direct the phone on a physical surface and activate the AR mode. In addition, we showed the participants how to feed, clean, and play with the dog, explained how to teach it voice commands, and showed the achievement system. We made sure that the participants understood the functionality and explored the various options available to them.

Participants were instructed that a successful completion of the study requires keeping the dog cared for - that is, prevent it from being taken away from them, which happens when the dog is neglected for two days. Participants were instructed that if the dog would be taken from them, they would receive only half of the payment. We instructed the participants to interact with the dog only when they are at home, to ensure similar social and environmental contexts between participants. While the application allowed the users to pay real money to obtain some premium in-game items, we instructed the participants not to do this during the experimental period.

When the study period was over, participants came to the lab and were interviewed regarding their experience. In addition, we administered the Enjoyment, Relatedness, and Psychological Ownership questionnaires.

### 3.3 Measurements

To capture participants’ personal characteristics, we adapted measurement instruments from the fields of organizational studies and psychology. Personality traits were assessed using the TIPI scale [25]. Participants’ proficiency with AR was measured using an adaptation of the Internet Proficiency scale from [22]. In addition, Participants’ prior experience in playing video and mobile games, including AR games, was assessed by several 7-point Likert scale items (e.g. “How often do you play mobile games”). Finally, participants’ relation (i.e. affinity, ownership) to pets were assessed during the interviews.

The semi-structured interviews served as the primary tool for capturing the perceptions of the participants. The baseline questions of the interview revolved around their overall experience, meaning that they assign to their interactions with the dog and the dimensions of

psychological ownership that they experienced over the virtual dog in their care. For example, we asked how would the participants describe their daily interactions with the dog, was it important and why, how would they feel if the dog was transferred to another user, changed, or deleted. In addition, we asked the participants to describe their routine with the dog and to characterize how they used the auxiliary functions of the application, such as in-app games, achievement tracking functions, etc.

The enjoyment, relatedness, and ownership perceptions questionnaire that we administered to the participants was based on the corresponding Likert-scale items from a variety of measurement instruments on psychological ownership that were previously used in the organizational settings [4,46,48]. The items for enjoyment were based on the description of the corresponding dimension by [57]. The relatedness items were based on prior works by [6,64].

### 3.4 Data Analysis

We analyzed the interviews using the thematic analysis procedure [11]. All interviews were transcribed and imported to Atlas qualitative analysis software. At the start of the analysis, we familiarized ourselves with the contents of all interviews, actively reading through it several times. After making sure that we were familiar with all the interviews, we started to generate initial codes, first at the technical level, and later at the interpretative level. Finally, we analyzed the resulted codes to understand the emerging analytical themes.

We employed a mixed deductive-inductive approach to the analysis, discovering the emergent focal constructs based on the concepts of relatedness, enjoyment, and psychological ownership, as well as identifying the emergent themes, without tying them to a specific theoretical model. In line with the semantic approach, we identified themes in the interviews based on the explicit meaning of the data and did not descend into the latent level of the analysis. Additionally, given the focus of our exploration, we concentrated our thematic analysis report on a detailed account of the specific group of themes around participants' understanding regarding the meaning of their interactions and the dimensions of ownership.

The study was performed in a non-English speaking country. All interviews were conducted in the participants' native language. The quotes presented in this paper were translated into English independently by two researchers fluent in both languages. Discrepancies in translations were discussed until a common translation was agreed upon.

To substantiate the qualitative findings, we also analyzed participants' responses to the questionnaire that measured enjoyment, relatedness, and psychological ownership.

### 3.5 Participants

Twenty students (16 female) from a large university took part in the study. Participants' mean age was 24.1 (SD=4.7). Prior familiarity with AR applications was quite diverse with the mean of 4.0 (SD=1.94) on a scale of 1-7. The participants were recruited using the university's Facebook page and were rewarded with an equivalent of 30 USD for their participation.

## 4 FINDINGS

All participants had prior experience with mobile games, but none played them regularly and none had previously played AR games. With the exception of one participant in AR group and one in VE group, all participants were familiar with and had used AR features in social network applications (e.g. Snapchat). All participants except one reported that they liked pets, and particularly dogs. 9 out of 20 participants (four in AR and five in VE) owned dogs.

The interviews average length was 45 minutes. Of the 20 participants that took part in the study, one was excluded from the analysis due to the low reliability of her data (failing to attend to the basic dog's needs and providing inconsistent interview answers).

Overall, the participants' used all of the application's functionalities extensively: tended to the dog's needs, played games, bought additional food and game items, and advanced in the in-game progress system. However, The initial analysis revealed substantial variability in participants' self-reported length of daily interactions with the dog, in both AR and VE modes. The self-reports were corroborated by the visual inspection of the virtual dog maturity (the more one engages with the application and interacts with the virtual dog, the more the dog matures), by examining the progress participants made on the game achievements ladder, and by analyzing the customization items gained by the participants (hats, toys, apparel items). In addition, we inspected the use of voice communication features and in-application games. These various features of usage were interpreted as indicators of engagement. We found the self-reported screen time to be highly correlated with the various engagement indicators. Namely, those reporting on high levels of application use: (a) had their dog grow at least one level; (b) taught their dog one or more voice commands; and (c) gained at a minimum of 7<sup>th</sup> level at the achievements ladder.

We, thus, operationalized *engagement* as the amount of time spent interacting with the dog, using the self-reported usage metric. We categorized the participants as "high engagement" if they reported on playing more than an hour daily, and as "low engagement" otherwise. The AR/VE mode and engagement levels produced four groups:



- AR and High Engagement (AR/HE): 5 participants,
- AR and Low Engagement (AR/LE): 5 participants,
- VE and High Engagement (VE/HE): 5 participants,
- VE and Low Engagement (VE/LE): 4 participants.

Analysis of the data obtained from the interviews revealed a substantial difference in participants' perceptions and behavior across the four groups. Table 1 presents the differences between the participants' groups on the number of comments related to the constructs of *enjoyment*, *relatedness*, *possession*, *responsibility*, and *territoriality*, as recorded during participants' interviews.

Group	Related.	Enjoy.	Possess.	Rspnsbl.	Trrtr.
AR/HE	15	24	11	27	14
AR/LE	11	8	7	11	5
VE/HE	3	5	4	9	2
VE/LE	1	6	1	4	2

**Table 1: Number of extracted quotes referring to the key constructs. Green color corresponds to a low number of quotes (1-4), yellow corresponds to a medium number (5-10), and red corresponds to a high number (11 and more).**

#### 4.1 Perception of the Dog as Real vs. Virtual

The difference in perception of the dog as an “authentic” being versus a virtual item or a game was clearly visible between participants in the AR and the VE conditions. Participants in both AR groups often described their perception of the dog as “just like a real dog”. Throughout the interview, the reasoning of the participants in the AR group was guided by the constant comparison of the dog in the application with a real animal. Despite the cartoony look of the dog, these participants emphasized the behavioral similarity of the virtual dog to a real dog and decided how to treat it according to their understanding of how to care for a real dog. For example, when asked to what she can compare the experience with the app, the participant answered:

*“[Thinking] umm... I think it is very much like raising a real dog”* [P1, Female, 27, special education student]

We noticed how the AR group participants were able to change their perception of the dog as a real or virtual object according to what suited them emotionally. For example, when one AR participant discovered that the dog is sick or sad, she regarded it as a virtual object, possibly to

counteract negative feelings that may rise when seeing a sick animal, stating:

*“Even if I am kind of attached to it, it is still not a real dog”* [P9, Female, 28, Graphic Design]

The same participant explicated that when she saw that the dog was happy, she felt the emotional connection to it “as if it were real”.

In contrast, the VE group participants referred to their interactions with the virtual dog as less real. In contrast to participants in the AR condition, most VE participants emphasized that because the dog is a virtual object, it is not something they take very seriously. For example, when asked what the participant felt when she discovered that the dog was sad, she answered:

*“Ummm nothing, first of all it is virtual”* [P4, Female, 23, Nursing student]

And when asked whether or not the dog is similar to the real one, another participant decisively answered:

*“[Nodding refusingly] It is not like a real dog”* [P4, Female, 24, English Literature student]

#### 4.2 The Virtual Dog's Meaning for Participants

A substantial part of the interviews with the participants was devoted to the discussion of what do the daily interactions with the dog “came to mean” for the participants, and how they think about the role of these interactions in their everyday life. From the answers, it became evident that most AR participants perceived the interactions with the dog as some form of “relationship”, while the VE participants defined the interactions more as a game that they play daily. The participants referred to relatedness and enjoyment as defining characteristics of what the dog ultimately means to them. In the following subsections, we provide a detailed account of how the different groups in the study related to these two qualities.

##### 4.2.1 The Ability of the Dog to Provide Enjoyment

Generally, all participants expressed their overall enjoyment from the study, stating that it was a pleasant experience, that the dog was “cute” and “funny”, and that the interactions with it were “fun”. Yet, while the AR participants reported on the virtual dog as the primary source of their feeling of enjoyment, the VE participants mostly referred to the games and achievements within the application.

Although enjoyment was expressed in all four groups, it was unusually high in the AR/HE group. The number of instances in which the participants in this group mentioned the enjoyment aspect to the interviewer was three times more than the other closest group. Interestingly, many of

the users in AR/HE group negatively referred to the gamification elements of the app. They disliked how the app encouraged them to play the games unrelated to the care of the dog in order to obtain virtual “coins”. Many AR participants explained that they spent all of the rewarded coins at once buying customization items for their dog (clothes, hats, toys, and food) and had to play the games repeatedly to have more money to invest in the dog.

In contrast, the participants in the AR/LE group, and both VE groups (VE/HE and VE/LE) reported a weaker emotional experience, and it was a less dominant theme in their discussion. We also observed that for two of the participants in the AR/LE group and one in VE/LE group, the overall fun that they experienced from the app was diminished over time and the task became more of a chore. Example quotes include:

*“At first it was more [I played more times a day] and I invested a little more time at the beginning. But eventually it's a little bit .... like, the frequency of playing has dropped”* [P4, Female, 23, Nursing]

*“At first, it's sort of nice, but then when it cries, you say “come on, what now” [smiles]* [P6, Female, 26, Occupational Therapy]

Interestingly, independent of engagement levels, participants in both AR groups tended to frame their perceptions in terms of the fun they had with the *dog*, whereas participants in VE groups related to the fun they had with the *app*. In particular, participants in the VE groups (and to some extent, participants in AR/LE group) reported on having fun playing the games unrelated to the direct interaction with the dog. The gamification elements of the app served as an additional source of motivation for these participants: they reported that their motivation was more hedonic - to enjoy the gaming experiences, and less instrumental - to obtain the coins to spend on the dog.

#### 4.2.2 The Ability of the Dog to Invoke Empathy and Relatedness

A substantial part of the interview was devoted to the discussion of the extent, to which the participants felt related to and empathy towards the virtual dog. Particularly, we asked the participants how they felt when the dog was happy, sad, or sick; whether they considered the dog as a part of their daily routine; and in what aspects the dog was important to them. In general, we found that while the AR participants were able to relate to the virtual dog's emotional state and experience relatedness, the VE participants did not.

For the AR participants, the expressions of the emotional attachment and empathy comprised a large part of the answers, indicating that the dog invoked feelings of

relatedness. For example, all AR participants stated that “when the dog feels sad”, it reflects on their mood too, and when the dog is happy, they too feel joy. This relatedness to the dog became a defining characteristic of the AR participants' interactions with the dog and motivated them to engage with it more, as illustrated by the quote:

*“Because really, every time I checked the dog, it was very important for me to play these games even when I did not have to. I could really you know, care for its basic needs, and no - I wanted to buy it hamburgers and luxuries and all these things so it would have more fun”* [P17, Female, 25, Economics student]

In contrast, most participants in the VE groups did not refer to emotion-related qualities of the dog. For example, on the question of “What does the dog and interactions with it ultimately mean to you?”, most of the participants in the VE groups stressed that there was “no special meaning attached to it” and no psychological needs that it satisfied because there were “no real consequences to this behavior” [P12, Female, 28, Occupational Therapy student]. The participants in the VE groups were motivated to play with the app mostly by their obligation to comply with the study's formal requirements. In addition, as already reported above, they explicated that they spent most of their time playing in-app games unrelated to the dog itself. E.g.:

*“Umm overall it was nice to play with it for three weeks. It was fun to play, earn money...”* [P12, Female, 22, Computer Science student]

*“It's not like ... it's nothing out of ordinary. It's not like I cared too much”* [P12, Female, 22, Computer Science student]

### 4.3 Experience of Psychological Ownership to the Virtual Object

We found that the feeling of psychological ownership of participants developed in the context of all ownership dimensions - responsibility, possession, and territoriality. However, the strength of the ownership feeling differed across the groups and the dimensions above. In general, the AR/HE group referred to ownership-related feelings very frequently and strongly, AR/LE group had weaker but still significant ownership-related feelings, VE/HE group only referred to the aspect of responsibility when discussing ownership feelings, while VE/LE participants referred to the ownership feelings very rarely or not at all.

#### 4.3.1 Responsibility

The feeling of responsibility for the dog and its “life” was the strongest dimension of psychological ownership that

emerged in the responses of participants in all groups. Particularly, the participants reported the responsibility to keep the dog alive and well, give it treats, play with it, keep it in a happy mood and, in one case, “walking it” around the house from time to time. Notice that this is much broader than the basic task required of them - to keep the dog alive. While all participants mentioned responsibility, it was emphasized much stronger in the AR groups. For example, in response to a question by the interviewer whether the participant felt responsible for the fate of the dog, one participant stated: “Unequivocally, yes” [P17, Female, 25, Economics student].

The participants felt the responsibility for the dog even in the context of diminished control over the situation. Particularly, we instructed the participants to interact with the dog only when they are at home. Most of the times when the participants returned home from work or study, they discovered that the dog was in a sad mood because they could not care for it during the day. In the AR groups, this sometimes resulted in the frequent feeling of “guilt”, as if they were partially to blame for the dog’s sad mood.

*“If it was sad, I felt a bit guilty about not using the app enough to care for it”* [P18, Female, 22, Social Science student]

Some participants even told the researcher that they considered going home earlier than usual because they were worried about the dog being unhappy and untended:

*“I felt terribly limited [in ways to interact with the dog]. Because I could not take care of it wherever I want, and sometimes I even felt that I need to go home because [the app] had already alerted me many times [smiles]. So I felt I had to go to give it what it needed”* [P14, Female, 24, Social Science student]

Both VE groups did not express guilt if the dog was unattended, and generally felt less responsible compared to the AR groups. In the VE/HE group, the feeling of responsibility towards the dog was often overshadowed by the responsibility felt toward the researcher (i.e. to fulfill the study’s requirements). The VE/LE group reported almost no responsibility towards the dog, and similarly to VE/HE group, pointed to the responsibility for completing the assigned tasks as the main source of their motivation.

*“Because you said to me at our first meeting: “Okay, this is your dog. Take good care of it, or otherwise, it will [disappear]. I wanted to do it well. I didn’t know what’s behind this, like I didn’t know how caring for it contributes to the experiment. It didn’t interest me, I just wanted to, you know, cool, this is the*

*experiment, take good care of it”* [P12, Female, 28, Occupational Therapy student]

#### 4.3.2 Possession

All the AR/HE group participants and most of the AR/LE group participants reported strong feelings of possession over the dog. The participants explicitly referred to the dog as “THEIRS”, as if they are its owners. On the question, whether it is OK if the researcher deletes the dog at the end of the interview session, signifying the end of the study, all participants in this group answered negatively, emphasizing that “This dog is mine” [P10, Female, 25, Law student]. They intended to continue playing, although one participant admitted that she will probably interact with it less frequently now that the study came to an end. During the interview, one participant did not understand clearly that the notion of deleting the dog was merely hypothetical. She thought that the dog was already deleted by a researcher. This resulted in a (mild) expression of anger and resentment:

*“Because first of all, it’s mine, why do you take ownership over something that is mine without asking me? And then you did damage that is irreversible, just out of spite, not of any good reason. Why?!”* [P17, Female, 25, Economics student]

In contrast to both AR groups, the participants in both VE groups did not explicate the notion of possession much. Even when they did, they tended to associate possession with the level of investment they put into the application’s gaming elements: leveling up, receiving achievements and in-game monetary rewards. For example, “advancing in levels” was a source of the possession feelings for P3 [Female, 24, English Literature student].

While in general, most participants did not see the reason to delete their dogs, one participant in the AR/LE group, two of the participants in the VE/HE group and two in the VE/LE group ultimately agreed to do it, perhaps due to their weaker sense of possession. An additional VE/LE participant stated that he would have no trouble deleting the dog if he did not like the dog’s appearance.

#### 4.3.3 Territoriality

The feeling of territoriality over the virtual dog emerged only in the AR/HE group in the form of the explicated desire to protect the dog from the changes by other users, refusal to transfer the dog to the researcher (temporarily or permanently), and reserving the right to interact with it only to themselves. The reasoning of the participants pertaining to why they want to protect the dog from others was mostly related to the high level of investment and the established connection between the participant and the virtual dog, as illustrated by the quotes:



*"I grew it, he's more disciplined, I taught him orders [smiling]. You'd get it already formed [smiling], you would not have to do the job"* [P1, Female, 27, Special Education student]

*"Because I felt like I was taking care of it, I brought it to where it is. And I feel like who would touch it will influence it"* [P14, Female, 24, Social Science student]

Only one participant in VE/HE and one in VE/LE stated that they would not give the dog to anyone even temporarily, not to mention allowing someone to change it. One AR/LE participant felt uncomfortable with the idea of sharing her phone with others, but the territoriality, in this case, was related to the device and not to the dog. Generally, AR/LE and the VE groups did not experience a feeling of territoriality. For example, on the question would he feel the need to protect the dog if someone wanted to change or harm the dog, one VE/LE participant stated:

*"Not too much, just because it's like virtual. I don't think I am attached to it enough"* [P15, Male, 18, Computer Science student].

#### 4.4 Perceptions of "Deletion": Dog vs. App

We noticed a difference in the importance participants felt between the idea of deleting the dog from the app or deleting the app itself. This was important for both AR groups and the VE/HE group participants. Three participants in AR/HE and VE/HE group, and four participants in AR/LE group clarified that if they have to end their interactions, they prefer to delete the app itself instead. Two AR/HE participants said that the act of deleting the dog is "cruel", and "immoral". One VE/HE participant expressed the difference as:

*"To delete the dog and [to delete] the game ... something stays, not, like, void, but ... it kind of feels bad. If you delete then delete everything"* [P3, Female, 24, English Literature student]

The VE/LE participants did not distinguish between deleting the dog and deleting the app.

#### 4.5 Findings from the Quantitative Analysis

Our study was designed as a qualitative account of a novel technological phenomena, and thus we employed the quantitative survey data only to complement to the qualitative findings. Our survey measured participants' perceptions of enjoyment, relatedness, and ownership towards the virtual dog. We confirmed the reliability of the survey instrument using standard procedures. An exploratory factor analysis with Varimax rotation yielded five factors corresponding to the 5 constructs in our scale,

Item loadings on relevant constructs were in the 0.78-0.91 range, above the 0.6 threshold [39] and all cross loadings were lower than loadings on the relevant factor. Constructs' Cronbach's alpha were all above the threshold of 0.7 [44]. Inter-construct correlations were lower than 0.5 except for the correlation between the Responsibility and Possession constructs (0.65).

Quantitative results were mostly insignificant most likely due to the small sample size (N=20). The exception was the analysis for the *enjoyment* variable. A one-way analysis of variance (ANOVA) on *enjoyment* showed that participants in the AR group experienced a significantly higher enjoyment levels (M=3.78, SD=1.86) when compared to participants in the VE group (M=1.68, SD= 1.03) (p=0.02). These results corroborate the findings from the qualitative analysis.

## 5. DISCUSSION

Previous research identified enjoyment, relatedness, and psychological ownership as key aspects that define our relationship with our physical and digital possessions. Our study examined how users relate to virtual objects in augmented reality as compared to a traditional virtual environment. To that end, we conducted an exploratory study where users cared for and interacted with a virtual dog for the period of three weeks. Half of the participants in the study viewed the dog superimposed on the physical world in AR mode, while the other half viewed the dog in VE mode, in a "regular" virtual application environment.

Participants in the AR group emotionally identified with their virtual dog and established an emotional connection with it. AR participants often referred to the dog as a real creature with needs, agency, and personality. It is possible that viewing the dog as an authentic being led them to allude to its emotion-related features. In contrast, the participants in the VE group did not connect emotionally with the virtual dog and mostly perceived the overall experience as a mobile game. This led them to interpret the dog solely as an entertainment device.

Previous literature suggests that perceiving an object as genuine and real, and the mere suggestion of the object's tangibility, lead individuals to experience stronger feelings to it [10,52]. AR technology enables the ability to embed the virtual object into the physical environment of the users. Thus, it implies a certain extent of "materiality" and "realness" to the virtual layer, especially if the users are able to interact with it. The participants in our study were able to see the virtual dog that appeared as a living active animal in their own living room. This may imply that the tangibility provided by the AR representation allowed the participants to ignore to a certain extent the graphical

simplicity of the dog's appearance and allowed them to perceive it as an active agent in the world. Hence their increased ability to relate and establish an emotional connection to it.

Overall, participants in the AR group experienced higher enjoyment levels. In addition, we also observed variations in the source of enjoyment between AR and VE modes. Because participants in the AR group viewed the dog as “real”, the primary source of enjoyment was the interaction with the dog (referring to the application's gamification elements as unnecessary and burdensome, often opting preferring not to play games). In contrast, participants in the VE group viewed the dog as a part of the overall game experience and mostly derived enjoyment from other in-app activities, such as games and achievements.

The AR group participants experienced the feeling of psychological ownership to the dog in the context of (1) feeling responsibility for the dog, (2) feelings of possession over the dog, and (3) feeling of territoriality and desire to restrict the access to the dog. The VE group participants, on the other hand, reported either very weak feelings of ownership, or not at all. Prior research shows that individuals are able to experience ownership to immaterial objects and entities, such as ideas, concepts, and even cultures [8,9,20,53]. Studies also demonstrated how the feeling of ownership develops in users of the conventional virtual environments [13,37]. In contrast to these prior studies, in our experiment the VE group participants reported almost no feelings of ownership for the dog. It may be that failing to relate to the dog affected the feeling of ownership of the VE groups. In addition, prior studies examined the development of ownership feelings in the contexts of users engaging in an intensive and long process of creation of a virtual environment (e.g. [37]), in the context of virtual items reflecting the identity of the users, such as digital photographs [18], or in the context of a customized virtual environment of the participants' private rooms [45]. In our study, the users could not create new content, and the interactions with the mobile app were brief and fairly limited. All the factors above could diminish the feeling of ownership for the participants in the VE group.

In addition to AR, engagement played a key role in the development of relationship with the virtual dog. Within the AR and VE groups, the highly engaged participants experienced most relatedness and ownership. While we could not assess causality at this stage, in traditional digital environments, engagement in the form of creating, changing, manipulating, and otherwise interacting with the virtual objects or digital informational content was previously found to be contributing to the development of psychological ownership toward these objects, especially in

terms of possession [7,37,56,65]. We extend this body of research by providing evidence on the importance of the engagement factor in AR.

Notwithstanding the importance of engagement, the AR representation of the virtual dog was the most powerful factor that contributed to the development of relatedness and ownership. It seems that the AR representation of the virtual dog was powerful enough for the users to ignore the relatively shallow experience of the app, and to develop emotional ties to the virtual dog. Even little-engaged participants in the AR group tended to develop stronger relatedness and psychological ownership when compared to highly engaged participants in the VE group. It is expected that with future increase in graphical capabilities of the hardware and in virtual artifacts' realism, users' perceptions of AR objects may grow closer to experiences in physical reality (rather than resemble experiences in purely virtual environments). This is in line with prior findings in research into human-robot interaction, where people related to robots as “hybrid” techno/living entities [33, 37].

The concept of presence may be useful to explain why AR may contribute to the sense of relatedness. In the context of virtual environments and computer-mediated communication, presence refers to the phenomenon of “feeling of being there in the mediated world” [60,69], and is closely linked to the experience of empathy [42]. It may be that what the AR users experienced in our study is the form of presence in relation to the “virtual object being present in the real world”. We propose to consider an “object's presence” to capture this phenomenon.

### 5.1 Design Implications

While prior research found that the users' relations to virtual artifacts are similar to relations with physical objects, physical limitations of manipulating physical objects may not exist in AR environments. For example, users might be able to reach and manipulate the virtual objects from afar, freely copying, moving, changing, or deleting them without a trace. If the object belongs to somebody else, diminished control over it coupled with the increased feeling of relatedness and ownership may lead to strong feeling of unfairness and resentment of the owner when someone interacts with her virtual possessions. Therefore, designers should seek to empower users by giving them a set of affordances that enable them to control who and when can interact with their virtual possessions, and what actions they can ultimately perform.

The feeling of ownership that the users experience toward their virtual possessions in AR may cause some existing design choices to be unacceptable. For example,

when one participant in our study thought that the dog was deleted from the app during the interview, she expressed anger and bitterness. Thus, practitioners should consider the possible manipulation of virtual artifacts in AR, as well as users' potential emotional response.

Another design implication pertains to virtual artifacts photorealism. Because of the relatively strong sense of relatedness and connection towards AR artifacts, participants' positive and negative emotions toward their objects may be amplified. For example, artifacts photorealism may lead to the "uncanny valley effect", where the users experiences shift from empathy to repulsion (as demonstrated in research into human-robot interaction [41]).

## 6 LIMITATIONS AND FUTURE RESEARCH

We compared between AR and VE modes using a mobile phone see-through AR application. The users either had to direct the phone towards the physical surface and look at the mobile screen to see the dog in AR mode or saw the virtual dog directly on the screen of the phone in VE mode. Given the recent developments in the field, future research should consider employing AR-glasses technologies to increase the immersion of the setting and provide the participants with more natural modes of interaction. In addition, using AR glasses invites comparison with virtual reality environments. Future research should seek to better understand and compare our relationship with virtual objects in these two modes.

In our study we used mostly self-reports as a primary indicator of the participants' engagement, corroborating them with several quantifiable indicators. Future studies could seek more objective measures of engagement, for example by logging participants' time and actions (using either built-in functions of the device's operating system, or external software).

We set a period of three weeks for our experiment guided by the research on the psychology of material possessions and material culture [8,20,54], which reports that the *gradual* incorporation of an object into the self, as well as an intimate knowledge of the object emerging over time, are necessary precursors to the development of a person-object relationship. However, different possible durations could have been set. Future studies should explore how the enjoyment, relatedness, and the dimensions of psychological ownership to the virtual artifacts develop in shorter or longer time periods.

Finally, our study offers an exploratory qualitative account of this novel phenomenon. We employed a relatively low number of participants, which made our quantitative data insufficient as definitive evidence of the

differences between the AR and VE modes. Future research should recruit more participants and seek to establish the causal links between the modes of representation and participants' perceptions.

## 7 CONCLUSION

We conducted a qualitative study in which 20 participants interacted with a virtual dog for a period of three weeks. Half of the participants the dog superimposed on top of the physical environment (AR), while the other half saw the dog on the screen of their device. We found that raising a virtual pet in AR caused the participants to perceive the dog as an "authentic" or "real" being. These participants also developed stronger feelings of relatedness and psychological ownership than the participants in a non-augmented environment, demonstrating the power of AR to induce an emotional connection and foster the relationships between users and their virtual possessions. We propose that AR practitioners should consider this power when developing AR applications. A useful analogy here is a privacy: the growth of social networks led in recent years to the availability of abundant data on users' actions online, which prompted companies to collect it and use it with few restrictions. As Harari argues [28], humans have thousands of years of experience in regulating the ownership of material possessions - land, resources, objects, and artifacts. What we don't have is experience in regulating or even understanding the ownership of data - and in particular virtual possessions. Thus, it took a few years for the risks and concerns introduced by the data-hungry companies to become apparent, which resulted in legislative efforts and the development of "privacy-by-design" approach to address these issues. We think that similarly, users would be better served by future AR technologies if an "ownership-by-design" approach is to guide the development of AR-based environments.

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