

# Normative Tensions in Shared Augmented Reality

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## ABSTRACT

Novel collaborative technologies afford new modes of behavior, which are often not regulated by established social norms. In particular, shared augmented reality (AR) - where multiple users can create, attach, and interact with the same virtual elements embedded into the physical environment - has the potential to interrupt current social norms of behavior. The objective of our study is to shed light on the ways in which shared AR challenges existing behavioral expectations. Using a simulated lab experimental design, we performed a study of users' interactions in a shared AR setting. Content analysis of participants' interviews reveals users' concerns over the preservation of their self- and social identity, as well as concerns related to personal space and the sense of psychological ownership over one's body and belongings. Our findings also point to the need for regulation of shared AR spaces and design of the technology's control mechanisms.

CCS Concepts: • **Human centered computing** → **Collaborative and social computing**; *Collaborative and social computing theory, concepts, and paradigms; social content sharing*

## KEYWORDS

Augmented Reality, Shared AR, norms, identity, psychological ownership.

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## 1 INTRODUCTION

Interactions in the social world are regulated by a set of behavioral norms defining what is acceptable and what is not. Novel technologies enable new forms of human interaction, often challenging existing norms of behavior. Augmented reality (AR) is one such technology that is expected to change the way we perceive and interact with the real world. AR allows the overlaying of a virtual layer of information or graphics on top of the physical world, enabling a level of contextualization as never seen before [4].

The current paper focuses on shared AR environments, in which multiple people can share the view of the same virtual object [56]. Figure 1 represents the idea of shared AR: multiple users equipped with tablets or smartphones can see the same virtual figure which stands on a real table. The unique nature of Shared AR, which allows combining a shared view of an augmentation or a virtual object in a real-world environment may significantly change our understanding of what is possible to do during social interactions. For example, one can easily create and replicate virtual elements and effortlessly anchor them to the real elements in the environment. The creator may also choose to hide the virtual elements from certain people or even attach an augmentation to another person without being authorized.

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Shared AR applications increasingly involve social interaction, thus making social norms of behavior a critical factor to consider. For example, the shared AR based social network WallaMe<sup>1</sup> allows the users to superimpose images and graffiti on the physical surfaces, and the virtual elements then become visible in these exact places to all users of the application. In the popular AR game of Pokémon Go<sup>2</sup>, users can interact with each other, competing or collaborating in augmented reality battles in a collocated physical environment.



Fig. 1. an example of the shared AR concept

Durham University’s Robert Seddon writes in his piece in *The Conversation*: “The design of physical environment carries intent, from statues telling us about notable people to walls obliging us to keep out – but AR adds an extra, optional, transformational layer, and it makes changing the meaning of that layer merely a matter of switching between apps” [64]. We posit that the unique ability of shared AR to interfere with the physical environment, as described by Seddon, could potentially lead to social tensions. For example, the creation and attachment of unacceptable augmentations in public spaces ultimately produces an unwarranted environment that may lead to tensions over responsibility and control. Moreover, attaching socially unacceptable or simply unwanted virtual elements to one’s private belongings (or even body) may cause personal distress and interaction avoidance. There is growing evidence for social misconduct in shared AR. In particular, people use and interact with each other in shared AR experiences (such as in Pokémon GO) in ways and places that are perceived as socially unacceptable [61]. The question of who, when, and where can create and engage with virtual AR objects becomes a cornerstone of building AR experiences.

Broadly speaking, our research is concerned with the acceptance of shared AR technology. Traditionally, research in the area has focused on factors such as usability and usefulness as key drivers of technology acceptance (e.g., the Technology Acceptance Model, TAM; [15]). More recently, research models in the area begun including social factors [35,75], social perceptions of interacting in public with technological devices [75], and normative acceptability of human-human interactions that are mediated through the technology [35,73]. Our study focuses on the latter factor: normative acceptance of interactions in shared AR environments. In particular, we aim to reveal the normative ambiguities and tensions that may emerge between users when interacting through devices that produce a shared virtual layer.

To date, studies on AR focused mostly on the technical and cognitive issues around users’ experience and interaction, while the social implications of technology use are mostly neglected. This is understandable, given that the technology has been in its infancy. However, the advancement in shared AR technology, coupled with the increased availability of shared AR

<sup>1</sup> <http://walla.me/>

<sup>2</sup> <https://www.pokemongo.com/>

applications, raises concerns over how shared AR experiences should be designed and used. As of today, there are no commonly accepted norms, ethical guidelines, or rules to regulate the usage of shared AR technologies in socially appropriate and ethically acceptable ways.

We advocate for a forward-looking approach and contend that now is the right time to start exploring these social norms in shared AR, hoping to influence the design of AR tools as the technology becomes increasingly adopted. Namely, the objective of this study is to inform design that will facilitate socially acceptable and ethical use of shared AR technology. More specifically, our goals are to (I) identify potential tensions and ambiguities related to social norms and expectations that are associated with the usage of shared AR tools; (II) determine ways in which these tensions may be addressed. To this end, we conducted an exploratory study of user experience in a shared AR context, aiming to gain insights into participants' perceptions related to the use of the technology. We simulated three possible social interactions between a pair of participants, whereby one participant facilitated the interaction, created a virtual object and attached it to the body, physical space, or belongings of the other participant (both participants were able to view all virtual augmentations). We used semi-structured interviews to capture participants' perceptions. Our findings highlight potential tensions over violation of several social norms including identity, personal space, and psychological ownership. We present study's participants' insights on how to create a safe and enjoyable social environment in shared AR and discuss practical implications for the design of socially acceptable shared AR experiences.

## 2 RELATED WORK

### 2.1. Social Factors in Technology-Mediated Interaction

The norms of public conduct are a crucial factor to consider when designing technology for social use [45]. Social characteristics of the environment as well as the expected audience influence the users' perception of the appropriateness and safety of technology use [58]. When technology interferes with what is considered to be socially appropriate in the particular context, the users feel uncomfortable and may attempt to avoid the interaction [74,75]. For example, early adopters of novel emerging technologies may attract negative attention from other people, which can create a stigma and lead to their social isolation [37,74]. A technological device, such as wearable smart-glasses, may be considered inappropriate for a public place [34] or be perceived as having features and attributes that violate other people's rights [16,33]. In a virtual reality example, the intrusion into the user's perceived private space led to the significant increase in discomfort and to negative reactions [73]. Thus, novel technology has the potential to negatively influence various aspects of human communication and cooperation by disrupting existing norms of behavior and by creating social tensions.

The established social behaviors and norms of the physical world remain mostly relevant in electronic technology-mediated environments [73]. For example, separation of public and personal spaces (or territories) is important for effective communication and collaboration in both collocated and distributed digital environments [18,30,63]. In another example, users regulate their activity on social networks by applying the principles of management of public appearance and exposure from the real world [29].

To date, most research on social norms in CSCW and related fields was done in the context of virtual reality [73], massive multiplayer-online games [18,31], online communities [9], and smart glasses [16]. Thus far, the research on normative aspects of augmented reality is scant. However, given that AR applications are increasingly being used in social settings, it is critical to consider social norms and the potential for normative tensions in shared (or collaborative) AR interactions.

## 2.2 Shared Augmented Reality

Augmented reality is a user interface metaphor, which allows for the interweaving of digital data with physical spaces [21]. Other definitions emphasize that the digital data in AR is spatially aligned with the physical world elements, and reacts to its changes [4]. The augmentations are typically represented by graphical objects [27], which can be either two or three-dimensional, and typically afford interaction. We can now experience AR using ubiquitous handheld devices such as smartphones and tablets [28,49], as well as through various head-mounted displays (AR glasses) and devices [16]. More recent conceptualizations of AR incorporate the notion of pervasiveness and define AR as a “continuous and pervasive interface that augments the physical world [...] while being aware of and responsive to the user’s context” [27]. This makes context-awareness the fundamental characteristic of AR, as the ultimate goal is to enrich the real environment with relevant information.

Rekimoto [56] defined shared AR as an environment that allows multiple users to share the same view of virtual objects (including any modifications of the object), where objects are overlaid onto the real world view. Billinghamurst and Kato [8] extended this concept by defining collaborative AR – a system that supports interaction and collaboration, and increases the shared understanding of the users. The two definitions are quite similar, however, in this paper, we use the former term, since we are relating to environments where the collaboration and interaction around the shared objects are kept to a minimum, and the focus is on the shared view.

The advantages of shared (or collaborative) AR as a communication and collaboration technology is in its ability to better refer to the shared virtual elements via natural interaction [54,78] and utilization of the spatial context of 3D objects that are situated in the physical environment [8]. Previous research mainly considered multi-user AR environments as a work tool and focused on technical and usability issues (e.g. [28,36,38]). Since then, the technology has advanced toward other areas, particularly in entertainment and social networking (e.g., Snapchat<sup>3</sup> filters, enabling augmentation of one’s face with graphical masks, adapting in real time to the facial movements and expressions). Substantial resources continue to be invested in overcoming technological barriers concerning the implementation of shared AR. However, only a few studies have investigated the potential impact of this technology at the level of the individual, group or society.

## 2.3 Social Concerns in Augmented Reality

The ability of shared AR to directly mix a digital plane with the physical environment surrounding us has the potential to greatly empower our social life. Because of its direct relationship with reality, AR has yet more power to elicit affective reactions, both positive such as empowerment and inspiration [48], and negative, such as unfairness [51], shame [2,68], or loneliness [50]. The mere fact of wearing AR glasses can evoke negative feelings in bystanders, who perceive the technology as a violation of their privacy and private space [16]. The disparity in information access may lead to tensions related to perceived fairness and equality [16]. For example, it has been demonstrated that even very basic augmented experiences raise concerns over fairness related to the distribution of informational resources [51]. Hence, wider adoption of AR may deepen the digital divide [46,70]. Moreover, AR affords increased interactivity and a novel intrusive modality, and these factors may act to reduce the perceived credibility of the provided information [67].

In general, technologically augmented environments encourage overproducing and over-sharing of digital footprints [7,22]. In Shared AR, these digital traces become critical to consider from the normative standpoint, as they are entwined with and are anchored onto the physical,

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<sup>3</sup> <https://www.snapchat.com/>

social world [26]. Because of the unique shared AR affordances, what may seem rude or tactless in traditional social environments may be perceived by some as normal and acceptable [7]. For example, the messages and objects left by the participants in social interactions can target specific individuals, be rude or abusive, and intrude on one's private property. Ambiguities that surround interactions in shared AR may lead to confusion and anxiety of the users [49] that may ultimately contribute to the failure of the technology's adoption.

To date, the potential of shared AR to disrupt the existing cultural and normative landscape, and the consequences of this disruption have been studied primarily in the context of information privacy. For example, Butz et al., [13] proposed a design solution for managing privacy in shared AR, while Wassom [71] looked at regulation of privacy in shared AR from a legal perspective. However, besides privacy, researchers and practitioners need to figure out a comprehensive normative platform that will ensure safe and productive social shared AR experiences. Our study is a first step aimed to understand potential threats to the existing rules of social behavior that this technology may introduce.

### 3 METHODOLOGY

We conducted an experimental user study simulating three possible social scenarios between pairs of participants around AR objects. In each of the scenarios, one participant facilitated the interaction, creating a virtual object and placing it over the primary participant's personal space or belonging. After the interactions, we assessed the participants' opinions via semi-structured interviews. Our focus was on the primary participants, as they were the recipient of the potentially threatening actions. However, both participants' perceptions and opinions were recorded, as often the facilitators placed themselves in the recipient's shoes, voicing what they believe were the participant's primary concerns.

#### 3.1 Procedure

Fourteen pairs, twenty-eight participants, were recruited for the study through the University's Facebook page and announcements throughout the campus. Participants received a monetary reward equivalent to approximately 10\$ USD. Participants were asked to arrive in pairs, already knowing each other beforehand. At first, participants were administered a number of general questionnaires assessing their personal and interpersonal characteristics. Where relevant, we adopted the appropriate measurement instruments from organizational studies and psychology. These included: age, gender, education, personality score (measured through TIPI - a 10-item personality measure scale [25]), tie strength (using an item reflecting the closeness or emotional intensity of a relationship between the participants [41]), trust in the other participant in the pair (assessed with an 8-item interpersonal trust scale [42]) and AR proficiency (adapted from the internet self-efficacy scale [20] - see Appendix B).

Upon completion of the questionnaires, we randomly assigned one participant to play the facilitating object-creator role and the other to play the primary role of the space proprietor (the person that owns the space or object to which the virtual augmentation is attached). The participants retained their roles for the duration of the study (all three scenarios). We then handed out the AR devices to the participants and introduced the applications to be used. We allowed the participants sufficient time to acquaint themselves with the applications and explore the various functions. All applications used in our study were real applications featured in the AR section of Apple's App Store.

Next, participants were introduced to the three scenarios, one at a time. For each scenario, a member of the research team provided the context for the shared AR interaction, guiding the participants to imagine the particular social setting where the interaction took place, for example, a classroom or an office. After making sure that the object-creator was comfortable with using

the application, and both participants understood the scenario's context, we asked the object-creator to choose a virtual object and anchor it to its intended location (i.e., on the possession or the body of the space proprietor). We then allowed the space proprietor to see the virtual augmentation using his handheld device. This procedure was repeated for the three scenarios.

After completing the three scenarios, a member of the researcher team conducted a semi-structured interview with both participants, discussing their feelings, attitudes, and perceptions regarding the AR-based interactions that just took place. The core questions (detailed in Appendix A) related to the issues of who and when can create, view, attach, delete or interact with the augmentations in each of the scenarios.

### 3.2 Scenarios

The three scenarios differed according to the physical anchor of the virtual artifact (see Figure 2 for illustrations). The scenarios were as follows:

**Body.** Participants were instructed to imagine that they are sitting together in a classroom during a class break. The object-creator was asked to activate the Facebook augmented camera application, which enables creating virtual masks, stickers, and other representations, and aligning them with the person's face. The object-creator was instructed to point the camera on the space-proprietor, and choose a sticker or mask (appearing on the participant's face in the app) (see Figure 2a). The assortment of virtual stickers and masks ranged from simplistic representations of facial features superimposed on the user's face, such as eye tint, or cartoony mustache, to full masks completely covering the face of the participant.

**Home.** Participants were requested to assume that they were both sitting at the house of the space-proprietor, casually socializing in the living room. The object-creator was instructed to activate an AR application that enabled her to release virtual dogs on the living room floor, close to the location of the space-proprietor (see Figure 2b). The virtual dogs and their actions were represented in an abstract cartoony style. The dogs released in the room left "footprints" when running on the surfaces and were also capable of making an impression of urinating on the floor (in which case the yellow puddle appeared on that place).

**Possessions.** Participants were asked to envisage an office setting, in which they both shared a workspace. The object creator chose from three virtual items (a figure of a zombie, an action figure, or a model of a house), and placed one of them on top of the space-proprietor's real personal belongings (her mobile phone, or a backpack). (see Figure 2c). As in the previous scenarios, the figures were not photorealistic but rather were designed in a cartoon-like style.

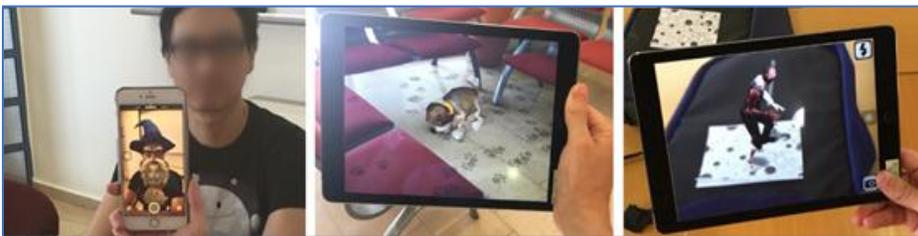


Fig. 2. The three scenarios used in the experiment. (a) Body: a virtual mask was aligned with the space-proprietor's face; (b) Home: virtual dogs were released in the living room of the space-proprietor; (c) Possessions: a virtual item was placed on top of the space-proprietor's personal belonging.

### 3.3 Data Analysis

We analyzed the collected material using the thematic analysis procedure recommended in [10]. Given the focus of our exploration, we concentrate our thematic analysis on a detailed account of

the specific group of themes around participants' understanding regarding social norms in shared augmented reality. We employed the inductive approach to the analysis, discovering the emergent focal constructs without an apriori list of themes or constructs related to a specific theoretical model. In line with the semantic approach to analysis, we identified themes in the interviews based on explicit meaning of the data and did not descend into the latent level of the analysis. Naturally, it is impossible to explore a social phenomenon without relating to the socio-structural and socio-cultural context in which this phenomenon occurs. However, where possible, we tried to report on the inner personal account of the individuals' feelings and motivations abstracted from the social origins of their behavior.

All interviews were transcribed and imported to Atlas qualitative analysis software<sup>4</sup>. 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 on the technical level, and later on the interpretative level. The technical codes in our analysis served to attenuate the personal characteristics of the participants: gender, age, and job/study. For each quote that we report below, we provide these contextual characteristics. Next, we associated each quote (and the related codes) with the origin scenario: *Body* [B], *Home* [H], or *Possession* [P]. Finally, we analyzed the codes to understand which themes are more salient at which of the scenarios.

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 to English independently by two researchers fluent in both languages. Discrepancies in translations were discussed until a common translation was agreed upon.

## 4 FINDINGS

### 4.1 Descriptive statistics

Of the 28 participants in our study, nearly half (twelve) were female. Participants' age ranged between 19 to 38 (mean age = 27.8;  $SD = 4.7$ ). All of the participants in each pair were acquainted with each other prior to the study, but the level of acquaintance differed substantially (mean acquaintanceship time = 5.1 years;  $SD = 2.4$ ). The participants' backgrounds were diverse. In terms of academic education: two of the participants held a doctoral degree, six participants – a Masters', twelve participants – a bachelor's degree, and four participants completed high school education. Participants also varied in terms of their profession: from unskilled workers, through clerical jobs, to scientists. Diversity also manifested in participants' prior familiarity with AR applications (mean AR proficiency score of 2.6/5;  $SD = 0.7$ ). Naturally, participants personalities also differed. The distribution of participants' age, AR proficiency, and personality scores exhibited near-Normal distribution (i.e., passing the Shapiro-Wilks normality test).

### 4.2 Overview of the findings regarding participants' concerns

Overall, we discovered that our participants had various concerns regarding the interaction in a shared AR environment. The idea of another person attaching virtual elements to their body, belonging or personal space was often considered inappropriate or even unacceptable. Concerns over one's identity emerged as one of the strongest themes in our interviews. Identity is a social construct, that can be defined in the context of "what and where the person is in social terms" [66]. Thus, the identity is both the inner experience of individuals of themselves and their perception by others [17]. Both aspects (which we categorized as *personal identity* and *public identity*) emerged as salient themes in the interviews. In addition, our analysis revealed two

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<sup>4</sup> <https://atlasti.com/>

additional themes describing participants' concerns: a feeling of *violation of personal space* and feeling of *violation of psychological ownership* over one's self and personal belongings. Ownership and personal space are pivotal concepts that help people to make sense and navigate their social and private lives [12,43,57,62]. These concepts are interrelated in a sense that the desire for personal "space" is often a precursor to the development of a feeling of ownership over that space [19,53,55]. Both these concepts have cognitive and affective components, which differ from the legal meaning of the terms.

The concerns related to identity, personal space and ownership largely determined the way in which participants experienced the interaction. Driven by these concerns, participants articulated the following two requirements for designing shared AR experiences: (1) designing mechanisms to control who can create, see, change, and interact with virtual augmentations that are placed over one's space or possessions, and (2) formulating clear regulation guidelines to content creation and rules of conduct in a shared AR environment. Figure 3 below summarized the salient concerns and key requirements that emerged from our study. In the sections below, we provide a detailed account of these concerns and requirements.

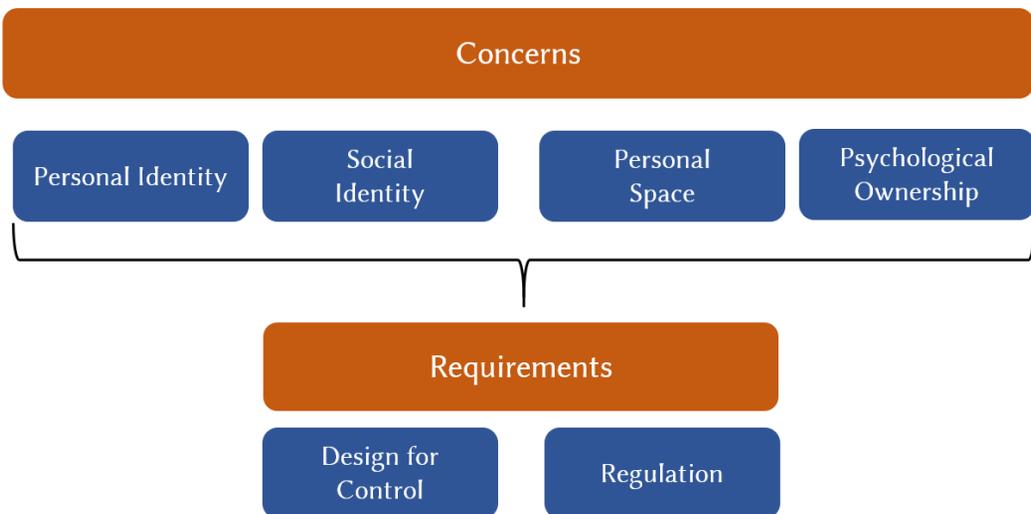


Fig. 3: Overview of the participants' concerns and requirements for socially acceptable shared AR experiences.

### 4.3 Concerns over Personal Identity

The vast majority of participants were highly concerned about the potential damage to their personal identity in both the *Body* and *Possessions* scenarios. These concerns are reflected in the following quotes:

*"There is some level of violation, even if I do not know that something was placed on me. [Violation] of me, of what I am at this moment. Like, something very basic."* [P12, female, 23, law student]

*"Personally, I would limit the possibility of such [augmentations]. If [the augmentation is attached] to some kind of clothes or glasses for that matter, this would bother me. Because glasses, ultimately, they are a part of my face, that's how I see it. It is an item that characterizes my personality."* [P4, male, 33, teacher]

Participants' quotes suggest that they integrated both their own body and their personal items into their sense of self on a deep and visceral level. Augmentation of these elements led to the overall perception of identity disruption.

In contrast to the *Body* and *Possessions* scenarios, the participants were less anxious about their personal identity during the *Home* scenario, as reflected in the quote below:

*"It is not that [the augmentation] is attached to me. It's just, like, around the room. I can decide who I allow to my room...."* [P5, male, 19, marine biology student]

We suspect that because the people can control who enters their home, the *Home* scenario was perceived as a "safe haven". Such a secure surrounding empowers one's sense of identity, where one can safely express oneself without threats. Thus, the participants were mostly unconcerned about the virtual augmentation of their home environment.

Interestingly, the object-creators seem to have recognized the potential threat to the space proprietors' identity. In the *Body* and *Possessions* scenarios, the object-creators were given the option to choose between a number of augmentations to attach. We observed that participants who attached the augmentations on their partners employed considerations related to their partner's personal identity. For example, when choosing between a virtual model of a house, zombie, and a monster, one object-creator has selected to attach a virtual house explaining this was because:

*"I think the house will not hurt him"* [P7, male, 26, IS student]

These considerations were most salient in both the *Body* and *Possessions* scenarios. Object creators explicated the feeling of uncertainty regarding placing a virtual augmentation on someone else. They reasoned that they cannot know what the 3<sup>rd</sup> party will consider as harmful.

We note that not all participants were concerned over their personal feeling of identity. In the *Body* scenario, we observed that the space proprietors were more readily willing to accept augmentations, provided they had the opportunity to review and approve what is being attached to their body. In the *Possession* scenario, several space proprietors expressed that they are not tied emotionally to the belongings to which the augmentations were attached, and thus were less concerned about virtual augmentations of their belongings. In summary, it seems that both the type of the virtual content and the physical object to which the content is anchored to play a role in participants' acceptance of the virtual augmentations, as well as influence the extent to which such augmentations were perceived as threatening their personal identity.

#### 4.4 Concerns over Social Identity

Concerns over one's social identity were among the most salient themes emerging from the interviews. All participants expressed concerns related to the potential damage to their social identity. Several users expressed their concerns using negatively charged words such as 'shaming' and 'bullying.' Some representative quotes are:

*"This is like shaming, but even more awful. [...] everyone can do what they please [regarding attaching the virtual elements to one's body]."* [P1, female, 28, office worker]

*"Instead of, say, this thing on your bag, someone can make you a hunchback. You are walking down the street, and everyone with an AR device can see it."* [P5, male, 19, marine biology student]

As with the case of self-identify, participants' fears were more commonly expressed in the context of *Body* and *Possessions* scenarios, whereas the *Home* scenario seems to have posed fewer concerns pertaining to participants' social identity. The participants emphasized that the settings of shared AR make managing one's social identity an overly complex and emotionally draining task, which requires constant vigilance and increased self-awareness. For some participants, even the mere imagination of such a situation seems to have raised stress levels, and in few cases

escalated to feelings of anger. One participant with an educational background stated that such settings would be “especially challenging for kids, as they yet lack the awareness to the effect [the augmentations] can cause and may use it to harm others” [P9, female, 24, marketing agent]. Another participant speculated that the technology may allow for someone to secretly place the augmentation over his body, comparing the effect to behind-the-back gossip:

*“It’s like gossiping about someone behind her back. And without her knowing when I do it.”* [P11, male, 28, accountant]

Others were concerned that shared AR would make it easy to socially profile people by tagging and marking them, thus negatively impacting their social life, as evident in the following quote:

*“Say, we go to the supermarket, and the augmentation implies that you should stay away from me.”* [P18, male, 23, security officer]

Three of the participants expressed their concerns over a particular form of “identity theft” in shared AR, when the perpetrator potentially overlays one’s facial features on top of another person, as one participant has commented:

*“My point is, if someone takes my face or someone else’s face and goes and does some illegal stuff, then this will trouble me quite a bit. Let’s put it like this - it would be very important for me to restrict this person from using the application.”* [P4, male, 33, teacher]

The size and type of the anticipated audience was an important factor that influenced the participants’ concerns regarding threats to their social identity. Most users emphasized the difference of the shared AR interaction occurring in a public space with strangers around, compared to a semi-public or private environment with mostly familiar observers. The participants were unsure of the reactions of unknown bystanders to the augmentations, whether it is ridicule, laugh, anger, or tolerance, and were anxious to reduce all possibilities for social interpretations of their identity by strangers. With known observers, social communication is usually more predictable.

As we reported earlier, there were almost no mentions of fear for public identity in the context of the *Home* scenario, for example:

*“It is something that [I] can choose to make completely private.”* [P13, male, 32, graphics designer]

*“In my personal space, it is my responsibility. I can do whatever I want.”* [P17, female, 21, economics student].

In the *Home* scenario, the participants felt they had control over the private space and the range of social interactions possible there. All participants emphasized their right to define who enters that territory. Even when asked to consider the augmentations’ potential to be provocative, participants did not express a threat over their social standing, probably due to the fact that those entering one’s home are likely to be friendly. One exception was a participant who expressed a concern that the augmentations will make her seem childish in the eyes of her friends [P2, female, 25, retail worker].

#### 4.5 Concerns over the Violation of Personal Space

Many participants, especially in the *Body* scenario, felt that the virtual augmentations were a violation of their personal space, for instance:

*“As I see it, it is ... an invasion of my personal space [...] even if it will be my brothers ... as soon as someone else with the AR device can see [the augmentation] ... this is an invasion of my space.”* [P10, female, 23, social worker]

Similar concerns were recorded in the *Home* scenario. Participants explained that a virtual object that is placed in one's territory violates that person's private space, just as a physical object would. An example quote is:

*"This is really your territory, your personal area, and I don't want someone to...just come and start doing these [augmentations]. It should come from me if I want it – I'll do it myself."* [P1, female, 28, office worker]

The *Possessions* scenario was also perceived as posing a risk to participants' sense of personal space, although to a lesser degree than when compared to the other two scenarios. In the *Possessions* scenario, participants' augmented possessions (i.e., handbags and personal mobile phones) were quite personal. Typically, such objects are held in close vicinity to the object's owner. Thus, when someone attaches a virtual augmentation to such possession, it entails that the augmentation's creator operates within the owner's personal space, potentially violating the sense of private space, as evident in the following quotes:

*"I don't want this. The very fact that someone can do something related to [my personal possessions] ... it feels like I am being touched... It is hard for me to accept it, just leave me alone!"* [P2, female, 25, retail worker]

*"Someone invaded my private space. It could be in my house, it could be on the street I am walking. [someone] pins all kinds of things on [my phone] and I [have to] delete them or move them ... it's very disturbing."* [P9, female, 24, marketing agent]

#### 4.6 Concerns over Violation of Psychological Ownership

Our findings indicate that in all three scenarios participants felt a sense of ownership towards the attached virtual augmentations. The majority of the participants explicated that when someone attaches an augmentation, it becomes the property of the person who owns the physical anchor, as illustrated by the following quote:

*"It is a question of to what it is attached, not who created the virtual thing."* [P13, male, 32, graphics designer]

Most participants considered ownership over virtual elements in terms of *possession* (i.e. "this item is *mine*"). Thus, participants assumed their rights to control the virtual augmentation and act upon it as they decide. Another way in which the sense of ownership was expressed was through a feeling of *responsibility*: several participants felt that they, and not the creator of the augmentation, were now responsible for any potential negative consequences associated with the virtual object (e.g. the augmentation offending someone). Psychological ownership also manifested in reference to the physical belongings. Namely, when someone anchored the virtual augmentations onto their belongings, the participants felt that their ownership over that object was compromised (such concerns were primarily recorded in the *Possessions* scenario). Naturally, participants perceived their belongings as their own, with all the associated rights. They clearly indicated that no one should be able to attach virtual augmentations to their possessions, except from when the person attaching the augmentation has been given explicit consent prior to the action. One participant stated:

*"I will not allow ANYTHING. This is really critical for me. MY stuff. Nobody is allowed to [create the augmentations]."* [P14, male, 31, programmer]

In contrast to the findings regarding personal identity in the *Possessions* scenario, we found no evidence for a linkage between the emotional significance of the physical objects and the perceived concern over psychological ownership. When asked whether it would matter to him if the augmentation were attached to his table, instead of his personal smartphone, one participant commented:

*"For me, it is still the same. It is my personal stuff. It is something that I would not agree to share with others."* [P13, male, 32, graphics designer]

#### 4.7 Requirement for Control over Attached Augmentations

As mentioned above, the strongest requirement expressed by participants in all three scenarios was for control over AR-based social interactions. The potential for abuse and the risks described above prompted participants to consider their recommendations for making shared AR experiences safer and more enjoyable. The most prominent requirement that was raised by participants was the ability to control all actions related to virtual elements placed in their physical environment. Namely, participants sought control over who can: (a) create (b) change (or delete) and (c) view the virtual augmentation. All participants agreed that by default virtual augmentations should be made invisible to the general public. For example:

*"I think that the right to decide who can view the augmentations should belong exclusively to me. Otherwise, who knows what somebody can do..."* [P6, male, 25, undergraduate student of geophysics]

Many participants articulated their desire to limit the exposure of the augmentations based on their interpersonal ties. By and large, participants sought to make the augmentation visible to their closest circle of friends and/or family, as illustrated by the following quotes:

*"It depends on the type of relationships between us. Let's say we are friends, so no problem, you can see it, cool, maybe you will even add something, and she will add too – it is a kind of interaction between us. If let's say, I put something on my partner, this is something between her and me and I may not want anyone else to be able to see it. It strongly depends on the context. In my opinion, If I put something on my friend, I want only our mutual friends to be able to see it. I don't think that someone else except us should see this"* [P11, male, 28, accountant]

According to the participants, the control over changing or deleting the virtual augmentation placed on their belongings (or body), even if someone else created them, should remain with the owners of the physical objects. At a minimum, participants suggested that explicit permission should be granted prior to creating a virtual augmentation to one's possessions, as expressed by one participant:

*"[No one] has the right to create or delete [the augmentations]. This option should be...limited. To limit it for modifications. To protect me.... so that no one could use it inappropriately. In every one of the cases, even in the home scenario."* [P9, female, 24, marketing agent]

#### 4.8 Requirements for Regulation

Participants called out for regulation that would ensure that the shared AR settings are safe and socially acceptable. According to participants, a mutual understanding of what is allowed in the AR "playground" could be established only by a normative and regulative framework, which would govern social interactions in shared AR places, for example:

*"Here we go into the matter of legislation. ... I don't want someone to come and say that I broke the law."* [P19, female, 33, researcher]

The majority of the participants expressed their concern over augmentations potentially being harmful or socially unacceptable. They suggested that virtual augmentations should be regulated in the same way virtual content is regulated in traditional social spaces. That is, what is considered socially unacceptable in physical, social environments, should also be unacceptable in augmented reality, as explained by one of the participants:

*"I would restrict the [virtual] content [available for creation], the options of what you can put [or attach]. This means to place certain limits on how far it [the technology] can go."* [P3, male, 27, research assistant]

Along the same lines, participants drew a comparison to norms and rules of behavior in other digital environments. They suggested that what is allowed in online social platforms, such as Facebook or WeChat, should also be acceptable in shared AR, as illustrated by the quote below:

*“I think from my experience it is better to do this like in WeChat. Most people, if they are friends, and they set up a long relationship with the software, they care only about the recent 3 days. [...] I think from this experience it should be the same. Then [the augmentation] disappears.”* [P7, male, 26, information science student]

Finally, participants highlighted the need to draw a distinction in regulation between what is allowed in private spaces versus what should be made possible in public augmented spaces:

*“There is the matter of private space and public space. Because in my private space, it is indeed my responsibility, I can do whatever I want. In the public space... I cannot do anything I want.”* [P17, female, 21, economics student]

#### 4.9 Personal Characteristics and tie strength

Our analysis of participants’ personal characteristics identified several factors that seem to have affected the extent to which participants perceived the shared AR experiences as threatening, namely: (a) age, (b) education, and (c) personality. Our findings suggest that older and more educated participants are more apprehensive towards shared AR technology. In particular, we found that those holding a master’s degree (or higher) expressed higher levels of concerns. Finally, those who scored highest on the introversion personality scale were among the most vocal opponents of shared AR (their concerns covered the various risks described above, especially emphasizing the risks pertaining to social identity and personal space).

Studying the level of interpersonal trust and the tie strength between participants in a pair, we compared the levels of high and low trust/tie-strength, only to find that differences were statistically insignificant when considering the number of concerns. Nonetheless, many space-proprietors indicated that they would only allow attaching virtual augmentation to their body or belonging to trusted others with whom they have strong ties, as evident in the following comment:

*“It seems to me that ... in my opinion if it was dependent on me, I would [give the right to see] the augmentations only to the people that we two [both object creator and space proprietor] trust enough and know them enough time to be sure they won’t abuse it or something like that”* [P1, female, 28, office worker]

In addition, analysis of interview transcripts suggests that the extent to which the object creators feel comfortable attaching the virtual augmentation on the space-proprietors’ body/belonging depended on the level of perceived trust, for example:

*“I will also think what I publish. Let’s just say that I will put [the figure of zombie] on top of the [space-proprietor’s] bag because I know her and know what she thinks. This action may be related to what we spoke previously, or something that is between us. But with others, I will think twice before doing things like these. I don’t know if we are on the same wavelength”* [P3, male, 27, research assistant].

#### 4.10 Summary of the Findings

Our study included three scenarios, which primarily differed in terms of the augmentation’s physical anchor: one’s body, personal environment (home), and personal belongings. Table 1 summarizes our findings, indicating the number of times that participants referred to each of the concerns and design requirements in each scenario. From the three scenarios, the *Body* scenario raised the most concerns related to the identity; the *Home* scenario seems to have raised elevated levels of concern over personal space, and the *Possessions* scenario was moderately threatening

across all focal concepts. Regarding requirements for the design of the technology, participants commonly expressed the desire to have more control over the augmentations attached to their body/home/belongings, and requests for regulation of the shared AR setting were also common (but to a lesser extent).

Table 1: Extent of participants' concern and requirement (and a number of comments) for each of the three scenarios. 2-10 comments were interpreted as "low," 11-20 as "medium," and over 21 comments as "high." The darker color of cells is associated with higher levels of concerns/requirements.

Scenarios	BODY	HOME	POSESSIONS
<b>Concerns</b>			
Personal Identity	Medium (13)	Low (6)	Medium (11)
Social Identity	High (27)	Low (2)	Medium (19)
Personal Space	High (39)	High (37)	Medium (14)
Ownership	Low (6)	Low (2)	Medium (16)
<b>Requirements</b>			
Design for Control	High (54)	High (40)	High (40)
Regulation	Medium (15)	Medium (13)	Medium (10)

## 5 DISCUSSION

Our study investigated users' perceptions of social norms in a shared AR environment in situations where one person created a virtual object and placed it on (or next to) the physical property of another person. We found that the distinct characteristics of virtual objects that are anchored to a physical reality has the potential to disrupt social norms and may give rise to tensions related to users' feelings of personal and social identity, personal space, and psychological ownership.

The participants felt that if their appearance can be augmented, their identity is threatened on multiple levels, leading to feelings of vulnerability and confusion. The literature in Psychology defines identity as an inter-individual concept that consists of mutual understandings of one's self by both the individual and those around him or her [6,17]. Identity has an important role in the regulation of social behavior [14,17]. At the personal level, identity consists of categorizations made by oneself regarding her understanding of self and the meaning of personal life. At the social level identity describes one's perception by others, and her standing within social groups and institutions [72].

The extensive body of research on technology-mediated communication, primarily in relation to computer games, virtual reality (VR), and mobile technologies, has paid much attention to issues related to users' identity. Virtual items and avatars were found to impact the individual's sense of self in 3D social gaming environments [39,65,76]. In addition, the notion of social identity emerged as a key factor in interaction with gesture-based mobile interfaces [1,34,75], where the users expressed concerns related to others' judgment. In the context of VR, evidence shows that the design of current social VR environments makes it possible for a user to harass and bully other users [44] and that social concerns hinder the usage of this technology [34]. Moreover, research has shown that novel social technologies, such as wearables, smart-glasses, and ubiquitous computing in general, may weaken users' control over the way in which they present themselves [34]. This is especially relevant in situations where the user is being observed by strangers [75] (a likely setting for the deployment of shared AR). Prior research in the context of the single-user non-shared mobile AR applications has established that it is essential for social AR applications to afford users the construction (and communication) of their identity [48]. We

add to this literature by showing that when AR is shared, users desire not only to communicate their identity but also to protect it from being violated by others in the shared space.

Concerns related to threats to identity are particularly relevant in public spaces where there is audience. Disruption of one's social identity leads to the experience of embarrassment [23] and stigmatization, and damage social well-being of the individual [24]. Prior research has demonstrated the importance of audience on the perception regarding the acceptability of technology-mediated interactions [59,74,75]. We add to the existing body of knowledge by showing how the unique affordances of shared AR lead to anxiety over one's identity. In particular, our study shows that the anchoring of AR objects onto the real world (as well as object's shared visibility) may lead to risks around the violation of self, as well as elevated concerns related to the loss of control over users' public appearance.

Another important theme that emerged from our analysis is the potential for a feeling of intrusion into one's personal space in shared AR spaces. Attaching augmentations to participants' body (*Body* scenario) or home (*Home* scenario) led to the perception that someone invaded the participants' personal space, leaving them with a sense of helplessness and apprehension. The space-proprietors found it difficult to accept that even if someone does not have access to the physical anchor (which they possess), they can still create and attach virtual objects onto it. Participants' felt threatened over their private space, sometimes exhibiting territorial attitudes, and at times leading them to reject AR technology.

The desire for personal space is a fundamental human need [19,53]. It depends on the social and cultural context [3,45], and is associated with an individual's feeling of privacy, security, and comfort. Incorrect or ambiguous understanding of what is considered a personal space in public places introduces potential issues in establishing a safe social environment

This is valid in the context of online environments, too, where users adopt the metaphors of private and public physical space to better manage their social relationships [18,30]. Typically, the users consider some space around their interactive zone as their personal space or territory and strive to protect that space [11,73,77]. Shared AR presents a unique setting for exploring issues of personal space. On the one hand, shared AR has the typical characteristics of technologically-augmented environments [7,22]. On the other hand, these virtual artifacts "spill over" to the real physical world, thus having actual physical consequences [26]. Since AR artifacts are ephemeral and immaterial, the creator of the AR artifact may be less sensitive to their implications in the real world. At the same time, the proprietors of the physical objects and space often relate to the virtual objects as if they were real. This could have a negative effect on the adoption of AR technology.

Psychological ownership was defined by Pierce [52] as "the state of the mind in which an individual feels as though the object or target of ownership is theirs." Psychological ownership has both cognitive and affective components [32,69]. Ownership can be experienced in relation to both material or immaterial objects, such as items, ideas, and places [17,52]. Overall, previous research in human-computer interaction and computer-supported communication found that violation of private space leads to defensive behaviors, avoidance tendencies, and feelings of personal discomfort [44,63,73]. We further confirm the critical value of personal space in regulating the interactions in shared AR. When discussing their shared AR experience, participants in our study indicated that they felt their ownership was violated. This was especially prominent in the *Possession* scenario, where the virtual objects were attached to the personal belongings of the participants. When a participant's personal item was virtually augmented, the owner of that physical object felt that her ownership was compromised. The stronger a participant's original sense of attachment towards the physical item, the stronger was the participants' feeling that her ownership was violated.

Perception of control over the object is an important precursor to psychological ownership [53]. The augmentation of real-world objects may disturb one's feeling of ownership through

depriving the person of exclusive control over the augmented object. If others can easily change the target of ownership without the person's control, one can no longer feel that the virtual object he created belongs exclusively to him. To date, research of psychological ownership in technological environments has primarily focused on fully-virtual environments. It was shown that users may experience ownership of digital content [5,47], virtual 3D objects [40], and results of work in collocated collaborative environments, such as shared screens [63]. The introduction of shared AR introduces a new set of issues, raising concerns over potential ethical and normative tensions. Our investigation revealed that when creating virtual artifacts in shared AR it is essential to consider the space proprietor's feelings of ownership.

Virtual augmentations have several unique attributes: they can be placed anonymously, are restricted only by the creativity of the creator, are not bounded by the ability of the object creator to physically reach the modified real-world anchor, and are easily duplicated. Nonetheless, being anchored to the physical world, they produce real-world consequences in terms of identity, personal space, and ownership perceptions. Previous works on wearable devices showcased the tension between the advantages gained by individuals using the technology and the potential risks to others [35]. As evident from our findings, a shared AR environment may further heighten such tensions.

We also note that participants felt most comfortable interacting in shared AR with people they know and trust. Corroborating findings from other technology-mediated communications, our study highlighted the importance of interpersonal relations. For example, during public interactions with gesture-based mobile interfaces, the audience largely determined the technology's acceptance [1,59,74]. Namely, the audience that promoted technology's acceptance included partner, friends, and family – the most trusted and close people – whereas interactions in the presence of strangers negatively affected users' intentions to adopt the technology.

## 5.1 Potential Multiplicity of Virtual Layers

The setting for our scenarios was a shared AR space where both participants were able to view the virtual augmentation. Still, participants' comments indicated a concern over situations in which not everyone is able to fully view the virtual layer. The AR experience is complex because it allows creating multiple virtual layers on top of a single physical environment. For example, one person can create a virtual object in a shared office space, while his officemate can create a different object at the exact same location (using a different application or a different "augmented space"). These virtual layers may have distinct properties and different access privileges, such that different people may be able to view the AR space differently. Some participants expressed their desire to have an ability to define the extent to which the objects they created are visible to others. Others requested that they be made aware of every virtual layer that is anchored to them (or to their possessions). Wassom [71] referred to AR as "the secret medium" accessible only to those with the necessary device. In the current study, we observe the complexity regarding layer multiplicity. In such cases, it is expected that space-proprietors would either strive to gain control of all possible virtual layers, so that they could neutralize any adverse consequences for them, or alternatively restrict the interaction all together.

## 5.2 Practical Implications

A direct implication of our findings is the need to consider ways to better enable users to maintain their identity, personal space, and ownership intact in a shared AR settings. In particular, we stress that it is not always recommended that users be given opportunities for boundless creation and manipulation of virtual objects, as there is a need to design the experience in a way that will protect the emotional safety of all participants. We propose that the normative considerations should guide the design of AR technology.

Designers need to strike a fine balance between enriching users' creative opportunities (enabling creators to construct their own virtual layers) and protecting other people through control mechanisms. Namely, we argue that application developers should provide a set of flexible control mechanisms that would enable users to decide who can create, view, modify and delete the augmentations. That being said, we acknowledge that designers cannot always fully control or design future technology-mediated social interactions, and these interactions also need to be regulated through social norms (or even rules). Thus, regulators should discuss and recommend what is to be allowed and what shouldn't be allowed in various shared AR settings.

We note that much could be learned from the literature on computer-supported collaboration in neighbouring fields, which long acknowledged that the affordances of novel technologies create opportunities for the disruption of established rules of public conduct [44] and thus should be carefully considered [75]. In particular, in line with the recommendations by Mcveigh-Schultz [44] for regulating social VR, we advise caution in designing social mechanics and anchoring techniques for shared AR. For example, we could consider allowing shared AR users to block attaching objects near them. In particular, Wilcox [73] found that people generally exhibit anxiety when a personal space of half a meter is violated in VR. We encourage future research to assess whether this or similar criteria may be applied to the regulation of personal space in shared AR.

The notion of audience could also be designed for. Altman [3] defined privacy as a dynamic "boundary control process", where people sometimes make themselves open and accessible to others, and sometimes restrict the access. Williamson [75] discussed the necessity for "Design for Strangers" that considers possible sustained spectatorship by strangers in public spaces. This is especially relevant to shared AR interactions where highly visual digital artifacts are created. Finally, drawing upon on the study by Riedl [60], we question whether the concept of *security zones* can be applied to shared AR spaces, such that "secure" and "open" zones will allow a different set of AR objects and interactions.

### 5.3 Limitations and Future Research

Our study has surfaced various concerns related to shared AR, adding to the scholarly literature in the area and offering practitioners some important insights. As with any exploratory study, this research could be extended along various directions. First, we explored only a limited set of social interactions in AR. The type of shared AR interactions that were explored in this study and yielded the insights into the normative tensions are already available in current commercial offerings of AR tools. For example, augmenting the faces of the users with virtual masks in real time is a popular feature adopted by many social networking applications, including Snapchat, Facebook, and Instagram. Placing animated objects on top of physical surfaces is a feature available in various AR applications. For example, IKEA's mobile application enables the user to try on the furniture by placing the virtual model of the item into the users' room. Overall, we believe that our study captured some of the key interactions that characterize state-of-the-art AR technologies. Still, we recommend that future research extend our study by exploring additional social situations.

Second, a potential limitation of our study is associated with the simulated laboratory setting, as opposed to studying interactions in their natural setting. However, the augmentations themselves were actually attached to participants and to their real possessions. Nevertheless, future research should seek to compare the findings of our study with more organic situations that arise in natural AR environments. Another limitation is the choice of the mobile AR technology that was used in our study. We used mobile AR applications, where users experienced augmentations through a handheld device's screen. While this is the primary form-factor in current AR use, there is no doubt that it is only a stepping stone towards wearable AR hardware.

Future research should seek to investigate tensions around social norms in alternative AR form-factors, in particular wearable AR glasses.

The participants were introduced to each experimental scenario in a specific order – BODY, HOME, and, finally, POSSESSIONS. Even though scenarios were analyzed separately, this specific arrangement may have introduced certain ordering effects, such as the novelty bias influencing the earlier scenarios and fatigue influencing later. Future research should account for this by counterbalancing the experimental scenarios.

The participant pairs in our study were familiar with each other prior to the study, at least to some extent. We tested to ensure that this did not influence the patterns of results. Still, it is recommended that future studies employ a more diverse pool of participants and explore how interpersonal dynamics influence the perceptions of social norms in shared AR.

Lastly, it is possible that the particular nature of the virtual content in our simulations influenced the participants' perceptions. For example, the masks fully covering the face in the first scenario could have biased the participants to adopt a negative stance toward the shared AR interaction. However, when probed on the matter, most participants indicated that the cartoony style of the virtual representations, their relation to popular movies and other cultural artifacts, and their short existence, lead the objects themselves to be perceived as not offensive. Rather, participants' concerns stemmed not from the content's characteristics, but from the objects' relations with the real physical space (that was "owned" by a different person). Nonetheless, we recommend that future research look into the effect of content type on social interactions in shared AR.

## 6 CONCLUSIONS

Shared augmented reality is a fascinating technological development in which people interact within virtually augmented real-life physical, social environments. To date, the majority of research effort has focused on the scientific and technical breakthroughs that make this kind of interaction available. However, research on normative and psychological aspects of AR-based interactions is scarce. Using an explorative qualitative research methodology, we provide initial insights into how interactions in shared AR give rise to concerns over social norms. Our findings indicate that creating, seeing, and interacting with virtual objects that are attached to physical anchors, such as one's body, objects, and environment, may disrupt users' feeling of identity, as well as potentially threaten people's feeling of personal space and ownership towards the physical objects. Such concerns could be mitigated through the design of AR environments by providing clear authorization and control mechanisms or by regulations of what is permitted and what is not permitted in these environments.

In the early days of the internet, the availability of log data prompted companies to collect unlimited data about individual's online behavior. In the years that followed, the potential risks to users' privacy were recognized, leading to the development of privacy norms and a global legal action to protect people's online privacy. Furthermore, privacy considerations are now part of systems' design (i.e., "privacy-by-design"). We draw parallels to shared augmented reality, arguing that the advent of shared AR as a novel form of human-computer interaction calls for the development of social norms that would regulate behavior in these realms.

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## APPENDICES

### Appendix A: AR proficiency scale

Adapted from: Matthew S. Eastin and Robert LaRose. 2006. *Internet Self-Efficacy and the Psychology of the Digital Divide*. Journal of Computer-Mediated Communication.

Please indicate the correct answer for every statement.

I feel confident that I:	1 Strongly disagree	2 Mostly disagree	3 Somewhat disagree	4 Neither agree nor disagree	5 Somewhat agree	6 Mostly Agree	7 Strongly agree
Understand terms/words relating to Augmented Reality							
Describe Augmented reality to others							
Can use Augmented Reality applications							

### Appendix B: Semi-structured Interview baseline questions

- What do you think about the appropriateness of such augmentations?
- Who do you think can view the augmentation? Why?
- Who can change and modify the augmentation? Why?
- Who can delete the augmentation? Why?
- Who can take a picture of it/store it/share it with others? Why?
- Who owns the virtual object?
- When the augmentation should disappear? Why?
- What will make this interaction unacceptable for you?