

Extended Reality Trans Technologies: Bridging Digital and Physical Worlds to Support Transgender People

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Extended reality (XR) technologies are becoming increasingly pervasive, and may have capacity to help marginalized groups such as transgender people. Drawing from interviews with $n = 18$ creators of trans technology, we examined how XR technologies do and can support trans people. We uncovered a number of creative ways that XR technologies support trans experiences. Trans technology creators are designing augmented reality (AR) and virtual reality (VR) systems that help people explore trans identity, experience new types of bodies, educate about and display trans stories and curated trans content, manipulate the physical world, and innovate gender-affirming surgical techniques. Additionally, we show how considering XR as an analogy for trans identity helps us to think about the fluidity and fluctuation inherent in trans identity in new ways, which in turn enables envisioning technologies that can better support complex and changing identities. Despite XR's potential for supporting trans people, current AR and VR systems face limitations that restrict their large-scale use, but as access to XR systems increase, so will their capacity to improve trans lives.

CCS Concepts: • **Human-centered computing** → **Mixed / augmented reality; Virtual reality; Empirical studies in HCI; Empirical studies in collaborative and social computing; Human computer interaction (HCI); Collaborative and social computing.**

Additional Key Words and Phrases: extended reality; augmented reality; virtual reality; mixed reality; transgender; LGBTQ+; technology design

ACM Reference Format:

Oliver L. Haimson, Aloe DeGuia, Rana Saber, and Kat Brewster. 2024. Extended Reality Trans Technologies: Bridging Digital and Physical Worlds to Support Transgender People. *Proc. ACM Hum.-Comput. Interact.* 8, CSCW2, Article 433 (November 2024), 27 pages. <https://doi.org/10.1145/3686972>

1 INTRODUCTION

Extended reality (XR) is an umbrella term that encompasses both virtual reality (VR) and augmented reality (AR), providing a comprehensive framework for the study of immersive technologies. VR is an immersive experience using computer graphics to simulate a 3D environment that a user can interact with in real-time [15], while AR is also immersive and interactive in real-time but adds computer graphics and computer-generated information on top of one's physical world environment [35]. While VR creates a virtual space separate from one's physical world, AR incorporates computer-generated imagery and information with one's perception of the physical world [12, 55]. XR goes beyond the individual definitions of VR and AR, offering a continuum that encompasses many

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2573-0142/2024/11-ART433

<https://doi.org/10.1145/3686972>

different ways of integrating the physical and virtual realms [67]. XR technologies are increasingly pervasive in everyday life; for instance, face filters have become ubiquitous in social media apps, and Apple's new Vision Pro XR headset's release in early 2024 garnered substantial attention from the public and the media. XR is a compelling research area as it fosters a deeper understanding of how both VR and AR technologies can create integrative and versatile experiences in a wide range of domains. As technology advances, studying XR is increasingly important to unlock new possibilities for the fusion of physical and virtual environments.

XR technologies have potential to help marginalized populations in substantial ways. While some research has examined XR's applications for marginalized groups [11, 17, 53, 59, 61], we still know relatively little about how recent technological advances in XR have been used to help particular types of marginalized users. Transgender people are one marginalized population that could especially benefit from XR, given that trans people often embody multiple physical and digital identities at once in complex configurations [38] which could align well with XR's unique ability to bridge physical and digital worlds. Especially given the current political moment, in which anti-trans sentiment and legislation has increased dramatically in many locations (e.g., in the U.S. and the U.K.), the trans population is in need of support. XR technologies could be further harnessed to address the needs of this underserved population. In recent years, advancements in XR have allowed the development of technologies that can more naturally mimic human movements and experiences. These advancements create potentially effective modalities for allowing transgender individuals expansive and safe new ways to explore their identities, tell trans stories, build empathy for trans experiences, and more.

To understand how XR technologies currently support and might best support trans experiences, we conducted an interview study with creators of trans technologies. Trans technologies include a wide range of types of technology, such as apps, online resources, games, art, supplies, and XR systems, that in some way help to address the needs and challenges that trans people and communities face [42, 43]. Of the 115 interviewees in our study, a subset of $n = 18$ had either created an XR trans technology system themselves, or discussed XR trans technologies in their interview, and we drew from that subset of interviews for this paper's analysis. Our focus on XR emerged because in our preliminary research [anonymized for review], many trans participants discussed XR's potential to address trans challenges. We further opted to highlight XR because our literature review identified a gap in understanding how XR can be used to support trans and other marginalized people's experiences.

We found that while prior work has focused primarily on how XR trans technologies support identity exploration, XR trans technology actually supports trans experiences in a number of additional creative ways. In addition to designing AR and VR systems that help people explore trans identity, trans tech creators¹ also create technologies that enable people to experience new types of bodies, educate others about trans issues, display trans stories and curated trans content, manipulate the physical world, and innovate gender-affirming surgical techniques. Additionally, some trans tech considered ways that XR technologies could explore the very concept of transness and trans identity, envisioning how to project the qualities and characteristics of transness into everyday life. Yet despite XR's potential for supporting trans people, current AR and VR systems face limitations that restrict their large-scale use. These limitations will hopefully be mitigated in the coming years as XR continues to gain traction and become more accessible.

In this work, we make the following contributions:

¹By "trans tech creators," we do not mean that creators were necessarily trans themselves. We mean that they were creators of trans technology. While 78% of creators in the subset analyzed for this paper were trans and/or nonbinary, some were cisgender.

- An empirical understanding of the current state of the art of XR trans technologies, which provides knowledge about XR technologies more broadly and technology design for marginalized groups.
- We expand on previous research about how people use XR technologies by instead examining the perspectives of people who create such technologies, which increases our understanding of current and future XR technologies.
- A discussion of how considering XR as an analogy for trans identity helps us to think about the fluidity and fluctuation inherent in trans identity [22] in new ways, which in turn helps to envision technologies that can better support complex and changing identities.
- A preliminary set of suggestions for future XR trans technologies.

2 RELATED WORK

2.1 Trans Technology

Trans people face a number of complex challenges in using technology, as documented by prior research in HCI. Social media, for instance, brings up issues like self-presentation, identity disclosure, and content moderation/suppression for trans users on platforms such as TikTok [23, 80, 81], Reddit [83], Tumblr [41], Facebook [38, 40], and across the social media ecosystem [24, 57, 66]. Trans identity also complicates technologies like voice assistants [3, 69] and dating platforms [32]. Further, trans people often face technological exclusion in algorithmic systems ([6, 47, 76], and across other types of technology [48, 82]. To counter the limitations and challenges trans people face in mainstream technologies, trans technology is technology designed specifically for trans people and communities.

Prior research in HCI has examined a wide range of trans technologies from several different lenses. Some researchers have studied or designed trans technology aligned with the more practical definition of trans technology as technology that addresses trans needs and challenges ([42]). For instance, Ahmed et al. [4] designed a trans voice training app, Liang et al. [50] designed a digital sex education resources for trans youth, Bierl et al. [10] designed an app to help support trans people in using public restrooms, and Pereira and Baranauskas [65] designed a safety app for LGBT Brazilians. Most of these studies employed community-centered and participatory design processes to ensure that trans needs were prioritized in technology design.

Other HCI research has examined trans technology from a more theoretical lens, drawing from Haimson et al.'s definition of trans technology as technology that "allow[s] trans users the changeability, network separation, and identity realness, along with the queer aspects of multiplicity, fluidity, and ambiguity, needed for gender transition" [41]. This definition relates to Sara Ahmed's concept of *queer use*, that describes the potential to reimagine possibilities for spaces and tools beyond their original intended uses [5] – such as using mainstream technologies' affordances in queer or trans ways [77]. Following these works, XR trans technologies may open up new possibilities for queer/trans use and queer/trans technological affordances, as we examine in this work. As a few examples of prior research that inquired into queer and trans technology uses and affordances, Beare and Stone [9] examined the queer nature of design in trans-focused telehealth platforms Folx and Plume, which they argue provides a "queer reimagining of what healthcare systems could be," and Baeza Argüello et al. [8] designed a facial augmentation tool that enables people to create new identities via Apple Face ID, which exemplifies trans technology's potential to embrace trans multiplicity. Existing theoretical analysis of trans technology investigates how engaging with technology from queer and trans perspectives can foster reshaping technological tools and systems themselves.

In the current research, we extend prior work by studying a sample of trans technology creators who work in one especially promising area of trans technology: XR. XR technology has the potential to help address trans challenges [42] both when it was designed with trans needs in mind, as well as due to its characteristics that encourage creative use. Studying trans technology designers' perspectives on XR trans technology is a unique context to explore both the practical and the theoretical implications of trans technology.

2.2 Extended Reality Trans Technology

A limited set of prior work has examined trans experiences with XR. In participatory design sessions with trans participants, many discussed AR's potential to address trans challenges, such as via AR mirrors and glasses that would enable people to see themselves in the way they envisioned their body [42]. Research has also found that VR can be an important means for trans and queer people to connect with similar others and exchange social support [1, 33, 34].

One line of research examines using XR technology for trans embodiment, such as through using avatars in VR or by exploring gendered experiences in AR. For example, some have posited that XR can build empathy and reduce bias towards trans people by enabling cisgender people to "embody" trans avatars via virtual reality [19, 71]. In contrast, rather than considering trans people as "others" for cisgender people to explore, XR can enable users to reflect on, navigate, and embody their own genders, identities, and bodies [1, 30, 33, 34, 46, 68], to the extent that VR can even be used as a therapeutic tool for trans people to explore identity [46]. Freeman and Acena [33] described embodied visibility, in the context of queer users in social VR, as a "conscious choice" to present and/or disclose one's queer identity by embodying a virtual body aligned with their identity. Avatar Creation Interfaces for VR games that give players agency and sufficient customization options can help to reduce gender dysphoria for trans players [68]. Rob Eagle, one of the participants in this study, has written extensively about their *Through the Wardrobe* AR exhibit, which enables audiences to experiment with gender presentations and embodiment through visiting and interacting with virtual and audio elements in a bedroom setup [30, 31]. Eagle found that presenting trans voices in AR enabled what they call a Thirdspace, defined as "a hybrid space where physical materiality and virtual media come together simultaneously offering potentially radical and transformative ways of understanding and experiencing the world" [31].

Though there has been limited research about filters as an AR for trans identity exploration and embodiment, one study examined trans people's reactions to gender-affirming facial filters, finding that participants were often dissatisfied with the filters' projections of gender, due to "loss of self-recognition" [37] and because the resulting images included heavily stereotyped gendered features [36].

In educational contexts, Paré and colleagues have examined how VR can increase trans and queer inclusivity in STEM [59–61], such as by enabling "playful experiences of inquiry about gender and sexuality" [60]. Mementorium, an immersive VR experience with a branching narrative about queer/trans experiences and marginalization in STEM, demonstrated how VR can help educators understand gender and sexuality better to help reduce inequities in education [59, 61].

Artist J Rosenbaum created an art installation that allowed viewers to experience classification errors when algorithms misgender trans and nonbinary people [72]. In doing so, they demonstrated how XR "creates a blurring of labels, of worlds, of reality, as many of us as gender non-conforming and non-binary people aspire to do in real life" [72]. Rosenbaum noted how XR enables people to tailor their worlds to go beyond the constraints of their bodies [72].

Perhaps the most fundamental and earliest example of XR trans technology is micha cárdenas's *Becoming Dragon* project, in which she embodied a dragon avatar in the virtual world *Second Life* for 365 hours, one hour representing each day of a year, to challenge the one-year "real life

experience” requirement to be eligible for gender-affirming surgery [21, 22]. cárdenas viewed this virtual world experience as “transreal,” which she defined as combining one’s physical body with a new identity using digital technology [22]. cárdenas posited that “interactions of the edges, where multiple realities collide, are precisely where transreal aesthetics can reveal political possibilities to viewers and participants” [22]. For cárdenas, XR is vital for trans identities because it does not privilege either the physical or the virtual, but rather the combination of the two and the messiness that arises when they join, just as during gender transition it is often impossible to separate one’s virtual and physical identities [22].

There are also several studies not focused on trans people that offer additional ways AR may be helpful for trans people. Lindlbauer and Wilson [51] introduced Remixed Reality, a form of mixed reality that enables changes to the physical environment: spatial (e.g., removing objects), appearance, temporal, and viewpoint. AR applications can also cover real objects with virtual visual information [7], which may be useful for trans people when the physical world is hostile. Additionally, facial filters that augment one’s face with digital content [70], explored by Kytö and McGookin [49], can allow people to “manually curate the digital augmentation they wish to present to others” and “present those aspects of self that are most important to them and avoid undesired disclosure.”

While research has shown how trans tech creators have leveraged XR to support trans needs, there is a gap in understanding how trans creator’s perspectives about XR systems could be leveraged to further understand and develop these technologies in ways that center trans values of embodiment, identity multiplicity, liminality, and exploration.

2.3 Extended Reality, Marginalized Groups, and Inclusivity

While the vast majority of XR research has excluded marginalized users, some previous work has examined relationships between XR and marginalized groups, including disability, race, gender, and intersecting and fluctuating identities [63]. XR technology has been examined as both a helpful tool and as a technology that could cause harm without proper consideration [26], and these benefits and harms could be even more stark for marginalized users.

In some contexts, XR systems have clear benefits for marginalized groups. The customizability and imaginative potential of online avatars support identity representation for disabled people, fostering accessibility and communication on online platforms [53]. VR tools have been used to experience various perspectives, allowing designers to design more empathetically for children, disabled folks, and other end-user groups with different needs [85]. Virtual worlds such as Second Life have been found to be feasible platforms to promote health behaviors and reduce social isolation for elderly adults [17]. VR technology can not only detect racial bias [62], it can also decrease racial bias among white and light-skinned people after they embody avatars with darker skin tones [64]. VR also has the potential to decrease discrimination in job interview processes and increase equity for applicants by limiting the amount of social cues available to recruiters [11]. In these instances, VR technology was both accepted and had low barriers to initial implementation, though some training was required.

While XR tools are documented to have benefits for marginalized individuals and communities, there are also risks that must be addressed to maximize their benefit while mitigating potential harm. For example, XR tools may enable both support and harm for mental health [58]. XR affordances like physical activity, social connection, mental stimulation, and a sense of autonomy can benefit mental health, while repeated rewarding experiences could lead to behaviors similar to addiction and potentially disrupt sleep rhythms [58]. Similarly, the newer use of social VR for dating apps can cause significant harm, especially for marginalized groups such as women and LGBTQ+ users, but designing around the concept of consent can help to mitigate harm for those engaging in this

technology [86]. Neurodivergent individuals may also face barriers with XR technology, as sensory overload experiences are worsened by excessive multisensory stimulation; the only solution to this issue is allowing users to customize their sensory experience, but XR designers and developers were found to be unaware of this accessibility need [52]. Moderating VR is also a difficult task, and improper or inadequate moderation can cause even greater harm for marginalized communities, especially when online harassment happens in real time [13, 75]. Many of these same limitations and potential harms are likely to exist in XR trans technologies, and future research and design must prioritize increasing accessibility and mitigating harm.

Our work expands on prior research in this space by examining how trans tech creators design and think about XR systems in ways that support trans people, a particular marginalized group. We also show how XR representations of transness and trans identity may be helpful to foster empathy and inclusivity among cisgender people and allies who may not understand the trans experience. By studying trans tech creators' perspectives on XR trans technology and its capacity to support and harm trans people in different contexts, we can examine ways that XR systems can innovate to better support this marginalized populations in the future.

3 METHODS

3.1 Data Collection

We completed 104 interviews with 115 creators and designers of trans technologies, and later selected a subset of 18 participants who had either created or mentioned XR trans technologies to include in the analysis for this paper (see Appendix A). This paper is part of a larger project that uses the full dataset [citations to our other publications anonymized for review], but because this paper focuses on XR, we narrowed our dataset. Trans technologies include a wide range of types of technology, such as apps, online resources, games, art, supplies, and XR systems, that in some way help to address the needs and challenges that trans people and communities face [43]. We specifically selected participants who met our predetermined criterion - being creators, designers, or developers of some type of trans technology - using criterion sampling [54]. After several years of observing the trans technology landscape, we constructed a list of trans technologies, and added to it by systematically searching for terms like "transgender technology" and "transgender apps" in search engines and app stores. We also used snowball sampling, asking each interviewee to list any other trans technologies that they would recommend for participation in the study. To invite participants to join the study, we contacted them by email or social media messages. Our response rate of completed interviews was 43.7%. We explicitly aimed to contact every trans tech creator focused on XR that we could find, and only four did not respond to our request for an interview. Interviews were semi-structured so that we could focus on topics participants considered most salient. We primarily conducted interviews via Zoom, and they lasted approximately sixty minutes (mean = 63 minutes, standard deviation = 12 minutes, range = 46-83 minutes). Interview topics included the story of their technology's ideation and creation, their design processes, challenges they faced, their thoughts about trans technology, and more. Each participant was compensated with a \$100 gift card or check.

3.2 Data Analysis

Interviews were audio-recorded and then transcribed for data analysis. First we open coded [18] all 104 transcripts and created a codebook throughout the process, then narrowed in to focus on the intersections of trans technology and XR for this paper's analysis. While the full dataset included many more codes and themes, in this paper we focus on those related to XR. Our data analysis approach was iterative and followed Braun and Clarke's [14] reflexive thematic analysis

stages: familiarization; coding; generating initial themes; reviewing and developing themes; refining, defining, and naming themes; and writing up. The first author led the coding process, but the process was collaborative in several ways. First, the first author discussed themes and codes and potential relations between the two with coauthors and other members of the research team on a regular basis throughout the year we collected and analyzed data. Next, the first and second author and several other members of the research team regularly wrote memos after conducting interviews and during transcription and data analysis, and we read each others' memos to inform our own thoughts about the data and its meanings. Finally, the first three authors reviewed the codes and themes presented in this paper and assessed their alignment with the data associated with each. While all 104 interviews informed the results presented in this paper to some extent, this paper draws primarily from the 18 participants who explicitly discussed XR reality in their interviews.

3.3 Participant demographics

Table 2 details participants' demographic and geographical characteristics.

Table 1. Participant Demographics

	Number (Percentage) (<i>n</i> = 18)
Gender	
Trans woman and/or trans feminine	5 (27.8%)
Nonbinary	4 (22.2%)
Trans man and/or trans masculine	3 (16.7%)
Cisgender woman	2 (11.1%)
Cisgender man	2 (11.1%)
Nonbinary trans woman	1 (5.6%)
Nonbinary trans man	1 (5.6%)
Race	
White only	12 (66.7%)
Latino and White	2 (11.1%)
Latina	1 (5.6%)
Asian	1 (5.6%)
White and other*	1 (5.6%)
Other*	1 (5.6%)
Age	
Mean: 36 (<i>SD</i> = 6, range: 22-45)	
Country of residence	
United States	12 (66.7%)
Canada	3 (16.7%)
Australia	1 (5.6%)
United Kingdom	1 (5.6%)
Spain and Switzerland	1 (5.6%)
*self-identified as "other" when asked about their race	

3.4 Limitations

Our sample of participants is substantially limited in its diversity, as the majority are based in the US and all are English speakers, which necessarily limits the perspectives about trans technologies

that we were able to hear. Additionally, the majority of participants were white. Our sample's homogeneity considerably limits our understanding of XR trans technology. Unfortunately, there are very few existing XR trans technologies, and as researchers we could not adjust the demographics of these creators. We also drew extensively from one participant's insights and expertise, which further increases the data's homogeneity. Finally, though we have in-depth data about XR as presented in this paper, we did not explicitly ask each participant about their views about XR trans technology; rather, we let the topic emerge naturally if it was salient for participants. We might have gained additional insights if we had specifically asked participants about XR.

4 RESULTS

4.1 Extended Reality for Exploring Trans Identity

XR tools can be an important mechanism for people to explore trans identity, and for gender exploration more broadly. As one example, Rob Eagle²³ created an AR experience called *Through the Wardrobe*, an installation where the visitor interacts with a physical room while wearing an AR headset (see Figure 1). As Eagle described,

Essentially what it looks like for you as the visitor, when you approach it, is that you see racks of colorful clothing... When you look more closely at each item of clothing, ...you see name tags on them and each name tag has a little icon... And so you, as the visitor, as the audience, are invited to take an item that catches your eye, that you're intrigued by, take it into the dressing room and try it on... And from there, once you have put on that item of clothing, then you are given a Microsoft HoloLens. It's an AR headset. That headset scans the tag itself, and then that launches the experience within the headset, which is comprised of five chapters, audio clips, and 3D animations. And these basically are mapped out within a room, a set that resembles a bedroom.

In trying on new clothing and exploring the AR experience, visitors are given the opportunity to explore their own gender identity by, in Eagle's words,

trying on items of clothing that might not necessarily be of their usual style, someone's daily style. And it's meant to make you question what makes you feel comfortable in your own body, what is the clothing that helps you to feel strong, powerful, what makes you feel vulnerable, what makes you feel sexy. And so you're asking yourself those questions.

While a tool like *Through the Wardrobe* might be especially helpful for people who are unsure whether they might be trans and need that space to explore, it also can be a way for cisgender people to explore and play with gender expression. Eagle described,

And you see a lot of people playing who are cis het, who might be very settled within. So they think within their gender, within their expression, and being able to put on some lipstick, for example, or being able to try on a dress in AR, that becomes a space for play. But I think there's also potential within that for a deeper transformation and a deeper form of questioning oneself. So I think AR is actually a very easy way, I think, for some people who might feel intimidated to go into a dressing room, especially when you hear the horror stories of some people being thrown out of dressing rooms for whatever these

²Most participants in this research explicitly wanted to be identified rather than anonymous, so we use their full names here, with permission. Other participants wanted us to use first names only, or pseudonyms, or wanted to remain anonymous. We report names based on participants' wishes in every case.

³We draw from our interview with Rob Eagle extensively in this paper's results, not only because Eagle was especially eloquent in discussing XR and trans technologies, but also because Eagle is an academic who studies XR as related to gender and identity (e.g., [30, 31]); thus, their perspectives are especially valuable in understanding this paper's topic. However, our extensive reliance on Eagle can also be considered a limitation of this work.



Fig. 1. Participant Rob Eagle’s *Through the Wardrobe* augmented reality installation, in which the visitor interacts with a physical room and the clothing in it while hearing stories about trans experiences. Reprinted with permission from Rob Eagle.

days. And I think AR actually becomes a really powerful ability for people to visualize themselves as something different.

In this way, XR tools can fill a gap, allowing people to explore gender in ways that often feel intimidating, or may even lead to harassment, in physical world contexts like clothing store dressing rooms. Eagle sees AR as a promising direction for gender identity exploration:

I’m not saying that all the youth are to become trans because of AR, but I see there’s potential within that as a way of experimenting with yourself, with the way you see yourself, with the way that you project yourself in the world.

VR, too, can be an important tool for trans and gender identity exploration, as documented by previous HCI literature [1, 33, 34]. Several participants mentioned VRChat, a VR virtual world online community, as an especially important place to explore identity. LemmaEOF, a VTuber⁴ and creator of the NameBlock browser extension which helps trans people remove their previous names from internet sites, described that,

People use VRChat to express themselves in ways they can’t in wider society. Exploring gender, sexuality, identity, and presentation and such... VRChat’s a really good place to explore gender just to come to terms more with who you are and who you want to be.

LemmaEOF particularly appreciated how the virtual world VRChat implemented mirrors: “[VR Chat] is such a good gender euphoria tool; mirrors are one of the best things to have ever been added to VR. You get to look at yourself in a body you feel more comfortable with. It’s really nice.” VR not only enables people to adjust their body’s image to align with their gender, or explore potential gender expressions that work for them, but also to see themselves and interact with others in that body. Clair Kronk, creator of Transpedia (an online encyclopedia of gender-related topics) similarly described how with VR, “people can test the waters with a gender identity in a way.” While previous research has described online gender exploration in text, image, and video-based online communities [16, 38, 39, 44], VR’s affordances enable a much more immersive identity exploration experience for many. LemmaEOF envisioned a future in which,

⁴A VTuber is a live streamer who appears on their stream using a virtual avatar.

I think we're going to get more stuff along the lines of stuff like VTube and VR Chat, ways for people to express themselves that is all their own. Being able to customize an appearance however you want is I think one of the big things that we've got coming. We're seeing the big pushback against stuff like Facebook's new VR avatars, and how boring they are. I'm predicting we're going to see an explosion of new ways to truly make something your own, not just built off templates, but ways to appear online however you want. I think that's going to be a really good thing.

As LemmaEOF described, future VR experiences can enable gender exploration in exciting new ways that go far beyond the current state-of-the-art.

While none of the trans tech creators in our dataset were currently working on creating AR face and body filters, several discussed the importance of this form of AR for gender identity exploration. For instance, GenderMeowster (they/them), a podcaster and streamer, discussed face filters as a form of trans technology that can help with gender dysphoria “*filters on Instagram that let you have a beard when you don't or something, or put makeup on your face when you don't have makeup on, those directly addressing gender dysphoria.*” Face filter AR mechanisms have gained popularity in recent years on sites like Instagram, Snapchat, TikTok, and FaceApp [45], and many trans people use these to envision how they may look as their desired gender [36], yet there remain open questions about how these tools relate to identity exploration. Eagle discussed the promising practical *and* intellectual potential of filters that enable people to try on different types of makeup and clothing for gender exploration:

How do forms of AR such as Facebook filters, or being able to try on clothing for eCommerce, things like that, how does that help people see themselves, imagine themselves in different ways? ...It might be something as simple as, “I really like this color of lipstick. What does this look like? I like this color of eyeshadow. What does that look like?” ...We've had these AR visualizers for a while, but I haven't seen really much in terms of research on what does that mean deeper down, more than just how does that result in a purchase, but what does that actually mean for the way that people see themselves?

Eagle further discussed the relatively surface-level status of current AR filters, and the potential for more substantial and deeper AR engagement with gender identity exploration in the future. The examples described in this section show how AR and VR uniquely enable exciting new forms of gender and trans identity exploration, as they allow people to try on new appearances via avatars and filters, and sometimes to interact in new ways with the physical world (such as in the case of *Through the Wardrobe*).

4.2 Extended Reality for Embodiment and Empathy

Embodiment, a term that once referred only to the physical world, now refers to presence in digital worlds as well, such as through avatars or presence in XR [84]. Embodiment, according to Dourish, requires not just “occur[ing] in real time and real space,” but also centers meaning-making. That is, embodiment enables people to find meaning in the world [25]. One prominent XR use in trans technologies is enabling cisgender people to embody new types of bodies and, in doing so, potentially build empathy for trans experiences. One of the primary systems that enabled such embodiment is *Machine to Be Another*, a tool in which two people, often of different genders, wear VR headsets and then “swap” bodies. As co-creator Marte Roel described,

And so what happens with The Machine To Be Another basically is that you see from the perspective, from the embodied perspective, of a real person on virtual reality. [...] Two people have a head-mounted display and a camera and one person's camera transmits to the other's head-mounted display, and vice versa. So it's basically a switch in the point of

view. And then we have a methodology for them to coordinate their movements, and then we interact with them, so we facilitate this experience. [...] We bring mirrors and we have developed it in a way [...] to enhance this feeling of embodying another.

Using this system, people can have a meaningful interaction in which they feel as though they are inhabiting the body of another person with a different gender, which Roel describes as “generat[ing] the illusion of embodying another person.” Yet *Machine to Be Another*, and even the team’s *Gender Swap* experience, was not built explicitly to enable trans experiences or trans identity exploration. Instead, the system was designed primarily for exploring embodiment and generating empathy. Roel explained:

There are these studies in social psychology, cognitive science, cognitive neuroscience, that suggest that by embodying a person from another group towards which you have stereotypical negative biases, by embodying them, there is a reduction in these biases. So say if white people with racial bias towards Black people embody a Black body, then there would be a reduction in the bias. And this is debated, [...] but I mean, this is a principle that we work on. If you were to see from the eyes of the other, would you better understand the other and better understand yourself as part of a system where we are othering others?

By enabling cisgender users to embody genders different from their own, then following the empathy argument, the *Gender Swap* technology may help reduce men’s biases against women. By this logic, the system could also potentially enable cisgender people to gain empathy for and reduce biases against trans people. For example, if a cisgender man looked down and saw a body traditionally considered feminine or female, he may better understand what gender dysphoria feels like for trans people.

Irem Harnak also explored how VR can facilitate empathy towards trans people, yet without trans embodiment, in her interactive VR documentary film *Made This Way: Redefining Masculinity*. In the interactive experience, using VR, audience members can approach several transmasculine people and hear their stories. Harnak described,

So they look like a video, but also they look kind of alive. They have some sort of volume to them. So you can approach them, you can go around them, look at them. It looks kind of surreal, but also really realistic... Everything is about body, the appearance, how you are, and we wanted to... not to turn them into avatars, but have themselves in that personal space.

In portraying trans men and nonbinary people’s experiences in an immersive VR environment, Harnak hoped to help cisgender audiences build empathy with trans people. “So we said, ‘Okay, maybe this is the thing. VR is about empathy. It immerses you into a place where you haven’t been. So let’s try to experiment with this.’”

Chitra Gopalakrishnan similarly created an AR experience to help build empathy towards trans communities in San Diego and Tijuana, working with a local trans organization called The House of Resilience, founded by Achi Vasquez. The resulting creation, *We Are All Made of Starstuff*, transformed a poster in a local shop window into an AR experience via the audience member’s smartphone (see Figure 2). The AR experience involved three-dimensional graphics along with audio of local trans women of color telling their stories. Gopalakrishnan described two primary audiences for the exhibition: “the folks who actually don’t believe in trans identities” and “young trans folks who are going through a lot of difficulties, and who maybe just need to hear a good story about someone’s positive experience” For the former audience, Gopalakrishnan hoped to build empathy for trans people:



Fig. 2. Participant Chitra Gopalakrishnan’s *We Are All Made of Starstuff* installation, which, via the viewer’s smartphone, transforms a poster in a local shop window into an augmented reality experience along with audio of local trans women of color’s stories. Reprinted with permission from Chitra Gopalakrishnan.

I started thinking about this idea that there’s this disbelief in trans experiences in our community. We hold back, we willfully suspend the disbelief when it comes to AR, or when it comes to playing Pokemon GO or something that’s not in front of us. I thought it was a really good overlap in how we can hold back disbelief about one thing, but not about the other, or empathy, empathy basically. I thought AR would give an excellent platform to build empathy.

By building an AR experience, Gopalakrishnan hoped that transphobic people may start to believe that trans identities were real and legitimate, in the same way that viewing a Pokemon character superimposed onto a physical location appears more “real” than a character in a video or game. In the current anti-trans political climate, more widespread use of XR for empathy building could help to decrease implicit biases without requiring trans individuals to interact with potentially hostile people.

Some participants remarked that AR technologies especially could be important tools for embodiment, due to their greater connection with the physical world and one’s physical body, in contrast to VR which were viewed as more disembodied. By combining physical and digital realms, AR technologies can enable people to reflect on their bodies and identities in new ways that help them to build empathy with trans people, but also sometimes to examine and explore their own gender [30].

While most of the trans tech creators quoted in this section viewed XR systems as important tools for cisgender people to build empathy towards trans people, scholars have critiqued empathic technologies as potentially appropriating queer and trans experiences [73]. Instead, it may be

more impactful and respectful for technologies to build compassion and sensitivity toward, and awareness of, marginalized genders without necessitating embodiment [73].

4.3 Extended Reality to Display Trans Stories and Curated Trans Content, and for Education

Trans technology creators also envisioned and used XR as a way to share and display trans stories and curated trans content, and educate audiences about trans experiences.

For many trans tech creators, XR was an important means to tell trans people's stories. Chitra Gopalakrishnan described how AR uniquely enabled the voices of trans women of color to be forefronted in the *We Are All Made of Starstuff* installation:

I did a lot of interviews of trans women of color in our community for this piece. Their voices were overlaid on the animations. So the pieces were not my story in any way, it was entirely informed by my conversations with them, including their actual voices in the piece. The goal was to have stories of optimism in the trans community, stories of role models in our community.... I felt like this piece really gave an... opportunity to provide voices to the younger generation primarily, but also, just to the general public.

The thing is, had it been only an installation, like a non-AR piece, had it been a piece that was an art installation that was posters or, I don't know, some other kind of media, my voice would have been the stronger one in the piece. But because of it being AR, allowing for voice, allowing for that first person's account telling, the storytelling, that's I think allowed for that. Any other media it might have been... video also, you can lose that experience because it's not immersive. The thing about AR was, I don't know, I felt extremely... the technology around it, the immersiveness of it... this is your headphones and you're looking at the thing, and it's really engaging.

As Gopalakrishnan described, the immersive nature of the AR experience was critical in conveying trans women's stories to audiences.

Irem Harnak's interactive VR documentary was another mechanism for sharing trans people's stories, using both visual and sound-based means.

I started photographing different people, ...and just going into people's personal spaces... and the way I was photographing them, they were sharing their life stories... It was a really personal experience. And then around that time I was thinking of finding another way. Apart from photography exhibits, how can you show it to more people what I lived, my experience of being one to one? And [trans men] weren't really visible then... It's like, "Who meets trans men on a regular basis?" So I just really wanted to see if I can make something where people are going to be immersed in that similar experience type of thing.

Harnak's film was a way to share transmasculine people's stories and to make them more visible, and in this way educate people about trans experiences. By combining personal stories with VR and spatial sound, Harnak made this educational storytelling experience immersive and meaningful.

Rob Eagle's *Through the Wardrobe* AR experience also included trans voices telling their stories. "You're hearing stories from other people talking about what they wear and the things that they do for their own bodies to make them help themselves feel more comfortable in their own bodies" This added storytelling dimension helped audience members to connect with trans experiences via first-person accounts.

Dylan Paré, creator of several queer and trans VR projects, considered VR from an educational perspective: "What might we do if we were trying to change the way we worked with VR in a classroom? If we worked with VR tools or social VR spaces to create a different kind of queered experience." [60].

In their projects, Paré also worked on using VR art tools with trans young people to enable them to tell their stories in an immersive way.

micha cárdenas used AR to educate people not only about trans experiences, but about how trans lives intersect with environmental issues:

I created this augmented reality project called Sin Sol about wildfires and how wildfires are affecting trans people and immigrants and disabled people and I'm working on a follow up project called Oceanic, which is about how climate change is affecting oceans and how that intersects with race, and gender, and experiences of loss.

In cárdenas's interactive AR projects, the immersive nature of AR helps audiences understand the high stakes of climate change along with experiences of transness and immigration.

XR was also an important way for creators to display curated trans content such as art, archives, museums, and historical content. As one example, artist Evie Ruddy created an AR art exhibition that highlighted trans and queer experiences.

It was last fall [2020], during Covid, I curated an art exhibition where I invited trans and queer and nonbinary people and Two Spirit to submit works that they have created in isolation. And I got a range of things, so there's electronic music and paintings that were in digital format. And then I placed them on street signs on a path along a creek, and so you'd have cyclists dismount, right? But you would hold your phone up. You'd open the app, hold your phone up, and then the artwork would appear.

In this way, Ruddy gave trans people who had been isolated the opportunity to share their stories and experiences with others via AR. K.J. Rawson, creator of the Digital Transgender Archive, considered that VR could be an interesting mechanism to potentially recreate scenes, places, and artifacts from the past that were important for trans history. XR can also be helpful for museum exhibits that display trans history artifacts. Chris Vargas, creator of Museum of Trans Hirstory and Art (MoTHA), described how XR could be useful as “a kind of reversing out of only existing in physical space to technology that is more of a hybrid of a virtual space and physical space. Something that rides that line that makes both a little bit more habitable” XR technology could help to make museum collections more interactive, accessible, and easy to navigate in both physical and virtual settings. Vargas also considered how VR for museum creation could be deployed in a more nihilistic, playful way:

I was like, “I'm going to create a game where the inevitable completion of it is the destruction of the museum.” And so you could explore the space, but then ultimately the space gets destroyed because of various reasons, all kinds of different reasons, like political and internal bureaucratic reasons and external, community backlash reasons, and it being irrelevant. So I imagined, “Oh, I could create the architecture of the museum and not be constrained by it being a physical space.” And make it as grand as I wanted to, but then ultimately, destroy it.

This type of disruptive experience can highlight the often precarious and ephemeral nature of trans stories and artifacts within cultural heritage institutions, while still making them temporarily visible. While destroying a physical museum space and its contents would be expensive and irreversible, VR would enable creative destruction without actually destroying museum contents.

In addition to her interactive VR film discussed above, Harnak also described a more novel mechanism for displaying trans experiences: AR trading cards of trans men.

So that was going to be the next stages of Made This Way where we were talking to Bklyn Boihood [a community of queer and transmasculine people of color]. Because at the time they had these calendars, all cool photos for every month. And then we were like,

“Yeah, guys, we should do something like this and then we can have different cards and then people can play.” And that was going to be an AR project.... So the cards come out and then you scan them and then each person starts talking about something, from stories or maybe they dance or something like that.... We were thinking of maybe pairing it with a book that could have some sort of a pop-up AR concept.

Rather than a formal museum or archive experience, AR trading cards could provide a lightweight and fun way of displaying curated trans stories.

In each of these examples, we can see the important ways XR helps communicate trans people’s stories, experiences, and histories to audiences in an immersive way that facilitates education.

4.4 Extended Reality to Manipulate the Physical World

AR also has the potential to transform one’s perception of the everyday physical world in ways that can help to make it more trans-inclusive and affirming, as documented in prior work [42]. While none of the creators in our dataset were currently designing and developing AR to manipulate the physical world, one creator did mention it as a possibility. Dev (@d3v-null), creator of a browser extension called Jailbreak the Binary that removes gendered language from one’s view of the internet, described the possibilities for deploying a similar tool in AR:

The technology absolutely exists for this. You’ve got Google Translate, right? You can just point that at any bit of text in any language, and it can translate into whatever language you want... If you want to speculate about future technologies, yeah, that’ll absolutely be possible with future technologies that are being developed at the moment, like with augmented reality, so superimposing a layer where you’re changing some text around or models around in your environment? Yeah, I mean, it’s totally feasible future technology.

Many of the browser extensions in our dataset manipulated HTML code to display web content differently in people’s browsers, an idea that can easily extend to text in the physical world. For instance, browser plugins that replace one’s pre-transition “dead name” with their actual name could also be deployed in the physical world, similar to how Google Translate enables users to point their phone at foreign text to instantly translate it. AR filtering technologies could also adjust trans people’s appearances (e.g., in mirrors) and even strangers’ expressions to decrease transphobic hostile glances, as described in Haimson et al. [42].

4.5 Extended Reality for Trans Surgical Innovation

XR tools play an important role in gender-affirming surgery processes, from aiding with procedure itself to patient-clinician communication. Surgeon-operated robotics have been becoming more common since their introduction in the 1980s due to benefits including more minimally invasive procedures, increased precision, and decreased risk of complication [78]. These tools foster innovation in gender-affirming surgery procedures in particular by decreasing surgery times and by enabling complex surgeries via less invasive techniques [27, 28, 79]. In our interview, Dr. Nabeel Shakir described the functionality of the da Vinci surgical robot, where the surgeon operates through a head-mounted display (see Figure 3).

First, the console is separate from the robot. The robot, the actual surgical robot, is on the patient, and is connected by cables, HDMI cables, very simple cables to the console, and the console is away from the operating table. The console has a place where you can put your head and it’s got speakers on either side, it’s got a three-dimensional viewer or visor, that you can see what’s on the screen, the screen has a head up display that overlays an augmented reality. A description of what instrument is in which arm, what settings you have it on, a three-dimensional representation of what the robot is doing in space, as



Fig. 3. The Da Vinci Robotic-Assisted Surgery System, that participant Dr. Nabeel Shakir uses to perform gender-affirming surgery procedures. The system involves an extended reality headset and hand controls that enable the surgeon to perform the surgery “remotely” from elsewhere in the same room. image info: “Robot assisted surgery,” licensed under [Creative Commons Attribution-Share Alike 4.0 International](https://creativecommons.org/licenses/by-sa/4.0/).

well as any alerts or messages. So, it’s a heads-up display, and you have joystick inputs that sit below that visor that you can control in the full six degrees of motion, or freedom. In addition to that, you have a bar that you can rest your elbows on in the middle of the bar, there is a touchscreen with additional inputs and outputs. So, it’ll give you certain warnings, you can customize it. If I want to swap my right and left arm what they do is I swap that there. There are foot pedals as well, the foot pedals switch, you know what arm is active. It’s like a clutch of a car... There’s a lot of maneuvering that goes on. So really, when we’re operating, we’re using our feet and our hands at the same time. It’s like playing an instrument.

The AR viewer is a crucial facet of this tool and contributes to increased innovation in gender-affirming surgeries as well as in the surgical field more broadly.

AR tools can also improve communication between trans people and their surgeons in the surgical planning process. Gaines Blasdel, who has worked with gender-affirming surgical teams and is training to become a surgeon, discussed how an AR tool could help individuals visualize different surgery outcomes, such as nipple size and placement as well as scar curvature. Blasdel described,

I think it makes sense in the context of a conversation with a surgeon and communicating what’s in your head. Right? So if it’s like, I have this vision of my scar, and I keep saying straight across, not curvy, and they’re like, “Okay, let’s boot that up and do it right now. And we can both look at it.” And so the surgeon says, “okay, when you say straight across, not curvy, this is what I see.” And then it gives the patient a chance to say “well, not that straight across, actually like this, right.” So from that perspective, I think it sounds really valuable for shared decision-making... From a clinical perspective, I think it’s a communication tool.

These XR tools can have a significant impact for trans individuals pursuing gender-affirming surgery in both the planning stages and execution. XR tools both foster clear communication as well as increase the success and efficiency of the procedures themselves.

4.6 Extended Reality as an Analogy for Trans Identity

Some trans tech creators viewed XR tools as a way to contemplate trans identity and to think about transness in new ways. For instance, Evie Ruddy, co-creator of the Transgender Media Portal (a site that chronicles trans films and filmmakers), described their thoughts on AR and drew parallels to trans identity, saying, *“I was thinking about [...] what is real and what isn’t real, and the trans experience of shifting. I just think there’s a lot of metaphorical similarities [...] between the technology of augmented reality and trans identity.”* Ruddy, and other trans creators, have the unique perspective of viewing XR as an allegory for trans identity because of the technology’s capacity to blur the lines between reality and imagination.

Irem Harnak, creator of mixed-reality documentary film *Made This Way: Redefining Masculinity*, similarly described how XR’s ability to manipulate space fits closely to trans experiences, saying,

When I started talking to trans people, I found this fearlessness of changing things, changing your body, changing everything. Just people starting testosterone... And I thought no fear yet, anything can happen, but it’s okay. So I keep thinking about wearables or VR also is really kind of a fitting technology for trans, I think. Also because VR is all about space and scale, being close to someone, and the technology we used was all about creating your body inside that space. So they’re not just flat, they have their dimensionality. So I thought that was probably really kind of close to the trans experience and the performance of it.

Harnak emphasized that XR technology’s premise of manipulating one’s body in virtual space is similar to the trans experience of changing one’s body and reconfiguring its relationship with the surrounding environment.

Rob Eagle, creator of the *Through the Wardrobe* AR exhibit, also made a connection between AR and transness:

I really think that AR is super transy. I think it’s super queer, it’s super genderqueer inherently, because it allows for transformation and for hybridity and for blending categories, and for really just fucking with norms and fucking with what is acceptable or what is accepted.

Eagle went beyond simply connecting AR to trans identity, asserting that AR is inherently trans because it enables transformation and deviation from established norms.

Some trans tech creators discussed XR tools in their capacity to illustrate more complex and abstract trans concepts, such as intermingling intimate embodied experiences with the bureaucratic challenges that many trans people face during transition. In our interview with micha cárdenas, she discussed using VR to question the one-year requirement of “real life experience” as a trans person, which was required for gender-affirming surgery in version 6 of the WPATH standards of care from 2006-2011 [22].

So that’s where I did this project Becoming Dragon, where that was my MFA thesis. [Questioning] the one-year requirement of so-called “real life experience” that trans people have to have before they get surgery, and so I lived in a virtual reality for 365 hours. Just over 15 days. I worked with a small group of artists then to make a motion capture interface for Second Life. So that when I moved around the room I was in, my virtual avatar of the dragon would move around in virtual space.

cárdenas questioned the year of “real life experience” requirement by asking if spending an equivalent amount of time living as a dragon in virtual reality would qualify her for “Species Reassignment Surgery.” Using the liminal nature of virtual reality, cárdenas called attention to the absurdity of

the WPATH gender-affirming requirement, while also illustrating that trans identity is too complex to be represented by a simple list of ideas or requirements.

Interviewees also discussed the large impact XR can have in enabling people to incorporate visual transformations into everyday life - a concept that is inherently trans. For instance, Eagle discussed AR's widespread implications for projecting trans concepts into one's surroundings:

the pervasiveness of AR, that it's in Zoom, it's in Teams, it's in so many platforms. It's built into these platforms. It's increasingly part of TikTok. So we're going to have a whole generation of young people who have all sorts of ways of layering their environments and layering the way that they see themselves in their environment, on the screen. If that's not trans, I don't know what is. That's being able to see yourself transforming and playing. And the instability of that, I think, is very, very powerful. The potential in that instability, I think, is really powerful for this young generation, a way of seeing themselves that I think was more difficult in older generations who didn't have these technologies.

This growing prevalence of XR tools can enable more experimentation and exploration of one's self-presentation in hybrid space. As Eagle noted, this has powerful implications, especially for younger generations who, by virtue of XR tools, have increased access to identity fluctuation and instability. Beyond the current uses of XR tools to transform living in distinctly trans ways, XR tools also have substantial potential for future transformations. In Eagle's words,

I think [AR's] trans potential is, I think, really quite exquisite within that. The way for us to see ourselves differently, the way for us to see our environment differently, that, to me, as I said, is super transy and I think points to the trans potential of AR.

As Eagle emphasized, there is more trans potential with XR technologies that have not been realized yet. In thinking of XR tools as a metaphor for trans identity, it is exciting to imagine the innovative future ways these tools can be used to consider and explore transness, and to reconfigure our physical and digital environments in transformative ways.

4.7 Limitations of Current Extended Reality and Future Directions

As much as XR tools hold great potential for trans technological innovation, current technologies are limited in several important ways. First, some XR technologies are expensive and inaccessible. Further, many gaps remain between some of the hypothetical and speculative XR ideas that participants described, and the feasibility of incorporating those ideas into existing XR technologies - an example of what Ackerman calls the sociotechnical gap [2]. Eagle described some of the access limitations of current AR hardware:

An AR headset is not very accessible. They're very expensive. That's why it's only within this installation. This is not an everyday object. If I wanted something that was for everyday engagement, I might use something like a mobile, for example, cell phone, because that's everyday technology.

Although mobile phones allow access to more users in everyday contexts, AR headsets have capabilities beyond what mobile phones can provide. Eagle explained, *"I think an AR headset, at least for right now, they are still special; it frees up your hand, it allows you to see your body, it allows you to see the environment with these virtual objects placed on top."* Eagle described seeing great potential for AR to become ubiquitous in coming years, such as via AR glasses or contact lenses, that could allow people to use things like face filters and display biological data in everyday life settings - both of which could be used to augment trans experiences.

While VR also has potential to improve and become more pervasive, it may not have as much potential for future trans technologies as AR. Harnak described the difference:

I think AR is more, in a way, inclusive, because... it's format agnostic. It can be on your phone, it can be on a tablet. Anyone can see it, in a way. It can be in a public display or just an app.

VR has been an important trans technology tool for over a decade already, such as in micha cárdenas's *Becoming Dragon* VR performance [20, 22]. As described in the sections above, VR has been an important tool for trans identity exploration and embodiment. Yet AR may be a tool more suited to trans technological futures, as it allows unique combinations of physical and digital environments that are yet to be explored.

5 DISCUSSION

In this work, we have shown many unique ways that trans tech creators think about XR as an important technological medium for trans technology. We described how XR can be used to help trans people explore trans identity, to help cisgender people build empathy for trans people through embodiment, to share trans stories or curated trans content (often as a way to educate about trans experiences), to manipulate the physical world, and as a means of trans surgical innovation. We discuss future opportunities for XR in each of these areas in Section 5.2 Further, beyond more concrete uses, we showed how XR can often enable thinking about trans identity in new ways, and viewing one's surroundings in transformative ways that can help with identity change and liminality. Yet XR tools, especially AR, are still in nascent stages, and are far from accessible and usable for most people, leaving open vast potential for future innovation in the realm of trans technology.

5.1 Extending Prior Research: Extended Reality, Embodiment, and Transformation

This research departs from prior research (e.g., [1, 33, 34, 36, 46]) in that we talked to trans tech *creators* rather than users, which is important for understanding differences in how the two groups view XR technology. While studying users helps identify how people use XR technologies in everyday settings, our approach of studying trans tech creators provides new insight because creators push the boundaries of what types of XR technologies can be created and how they may change our world. Further, creators of trans tech XR are a unique group of people who have both the skills and motivation to create novel new technologies. However, the most transformative technology design will happen when XR users and creators work together; as prior research has shown, it is important that trans tech creators include trans people and communities in design processes, so that the resulting technologies are focused on community needs rather than on one individual's conception of what should be created [43]. As future XR trans technologies are created, we hope to see participatory and community-based design processes that involve trans community members in determining what should be designed, and how.

As Dourish describes, digital embodiment “turns action into meaning” [25]. For trans people, whose embodiment is often in flux, having a way to establish digital embodiment is especially vital. XR systems make this digital embodiment possible in unique ways. For trans people using XR technologies, the *action* is using an XR system and the *meaning* is reflecting on, experimenting with, or settling into a trans identity. Because XR tools can bridge physical and virtual worlds, and because they can enable people to present differently in each, XR is a medium that can help to illustrate identity fluctuation and fluidity, and to make changing identities and bodies more real via technology [22]. Performance artist, game creator, and trans theorist micha cárdenas (also a participant in this study) argues in her work that transformation and fluctuation connect trans identity and XR, and that XR's inherent liminality uniquely enables exploring transness [22]. cárdenas describes how “mixed-reality performance can serve as a liminal space of training,

creation, and development for new unimagined assemblages of desire, resistance, and becoming” [22]. Yet living in a liminal state can be difficult. For many trans people, especially during periods of substantial physical and social changes, fluctuation and fluidity are essential parts of being trans, yet both can be confusing and difficult to conceptualize. Regarding liminality in the context of her own identity, cárdenas writes, “I am between realities. I can imagine what I want to become and then choose to become that new thing, but it is radically ungraspable, inconceivable. I can never know the reality of what I am choosing to become, desiring to become.” Further, she discusses the fluid nature of trans identity in different social environments: “Speaking, being with different people throughout the day, my body and name changes, my realness or unrealness oscillates” [22]. XR’s liminality produces tools that bridge physical and digital worlds, and creatively represent trans identity and bodies; such tools can help trans people navigate the confusion inherent in their own liminality. As we show in this work, XR provides many different ways to visually represent and inhabit trans identities and complex, changing bodies, which can help to make sense of liminality, and capture its meaning, without simplifying it. Thus, building from cárdenas’s conceptualizations of transness and XR and Dourish’s understanding of digital embodiment, we highlight how, by bridging physical and digital worlds, XR trans tech makes action meaningful during times when one’s identity and/or body are changing.

5.2 Future Opportunities for Extended Reality Trans Technologies

While prior work at the intersection of trans and LGBTQ+ identities and XR has primarily examined XR’s potential for identity exploration [31, 37, 46], support exchange [1, 34], and education [59–61], we show that such uses are just the tip of the iceberg for XR’s potential in the world of trans technology. In particular, there are substantial important XR uses, both current and future, in each of the areas we examined in Results. While our research only examined technologies that currently exist, we can extend the ideas discussed in this paper to the future of XR trans technologies. Some of the ideas and directions participants discussed for future XR trans technologies are hypothetical and optimistic potential technologies that do not yet exist. To draw these ideas towards more practical and feasible directions, in this section we describe exciting future potentials for XR trans technologies. Our work provides empirical evidence that can inform how to design XR in ways that are not only trans-inclusive, but can help to represent and affirm trans identities and bodies. While a comprehensive list of trans-inclusive or trans-affirming XR principles is beyond the scope of this paper, compiling such guidelines is an important goal for future research. Here, we discuss a few preliminary suggestions that draw from our results.

5.2.1 Exploring Trans Identity. In their work on trans people’s responses to using face filters (a type of AR), Teddy Goetz provides several recommendations for how facial filters could better support trans people [36]. Design suggestions include enabling subtle and customizable tuning for gendered features, allowing trans people to envision how they would like their potential future gender to look, being gender-neutral, allowing users to mix and match different gendered features, facilitating “unbounded exploration,” and helping to reduce internalized transphobia and binary gender norms [36]. Some of these suggestions could also apply beyond face filters to XR more broadly, especially when it is used for trans identity exploration. For instance, customizable appearance tuning via usable controls, enabling mixing and matching features rather than assigning particular features to each user based on binary gender conceptions, and making identity exploration as unbounded as possible would all help to improve XR-enabled identity exploration.

5.2.2 Embodiment and Empathy. Given important critiques that empathy technologies enable dominant groups to appropriate marginalized people’s experiences and then easily walk away

afterwards [56, 73], we question the extent to which future XR trans technologies should provide cisgender people windows into embodying trans experiences. Instead, XR technologies for embodiment may be most helpful for people who are questioning their gender identity to try out different bodies and identities in an immersive and interactive environment. For cisgender audiences, rather than embodying trans identities, XR could follow Irem Harnak and Chitra Gopalakrishnan's lead and expose cisgender people to trans stories and put them into conversation with trans avatars, as we discuss in the next section.

5.2.3 Furthering Trans Stories and Education. As described in Results, Irem Harnak, Chitra Gopalakrishnan, and other XR trans tech creators are doing important work using trans stories to educate non-trans people about trans experiences. Additional XR technological interventions could provide immersive education for trans people to learn about trans history and notable trans historical figures, learn how to reduce their own internalized transphobia, or learn tips for maintaining trans wellbeing and safety. Other XR innovations could combine storytelling with trans XR as an analogy for trans identity, such as by documenting trans people's experiences presenting in fluctuating and fluid ways via combining digital and physical environments with AR, and then enabling others to experience those stories via VR.

5.2.4 Manipulating the Physical World. Future XR trans technologies could help to adjust trans people's perceptions of the physical world. For instance, augmented mirrors or glasses can help people view their bodies in ways that align more with their identity [42], which could help mitigate gender dysphoria. Further, AR can erase aspects of the physical world that may negatively impact trans people, such as transphobic words and references to one's dead name.

5.2.5 Trans Surgical Innovation. Trans surgery could benefit substantially from XR innovations. As one example that combines surgical innovation with manipulating physical environments, an AR mirror could enable a trans patient, in collaboration with their surgeon, to view what they would look like after undergoing gender-affirming surgical procedures, and even to adjust parameters to achieve their ideal post-surgical outcomes. Further, surgical robots like the Da Vinci could use XR to create enhanced visualizations and simulations that help surgeons try out new surgical innovations without experimenting on patients.

5.2.6 Art and Games. We can also see many future potentials for XR trans art and games, such as innovative new installations and game experiences that involve trans representation and embodiment along with flexible and transgressive narratives and interactive experiences, central tenets of queer and trans games [29, 73, 74].

These are just several preliminary speculative examples, but they show the potential for building on and combining some of the themes we presented in this paper to create trans XR futures. We look forward to a future involving substantial growth and expansion in XR trans technologies that can help to improve trans lives in innovative ways.

As trans tech creator Rob Eagle stated in Results, XR's pervasiveness and growth, particularly among younger generations, is exciting. It will be especially notable to see what younger generations, who will grow up with face filters on their phones and headsets like Meta Quest and Apple's Vision Pro "spatial computing" device as standard, decide to create. Future XR designs will not be hindered by the access and technical limitations that we currently face, and will be able to innovate far beyond the possibilities that we currently see. However, there is also the possibility that as XR becomes more prevalent in everyday tools (rather than something that the user must explicitly seek out), it may shift from being creative and exploratory to more rigid, as designers have fewer options in exchange for functionality and ease of use. For instance, Apple's new XR device involves

strict design guidelines for developers, which may impose stringent boundaries and hinder creative expression. If XR can maintain its creativity and exploratory nature to enable meaningful trans embodiment, then even as it becomes more mainstream, the future of XR trans technology is bright.

6 CONCLUSION

We have examined the world of XR trans technologies: technologies that use XR to create new virtual or hybrid spaces that support trans people in some way. These technologies range from systems that enable identity exploration, to experiences that help cisgender people to understand and empathize with trans people, to educational or curated displays, to ways to innovate gender-affirming surgeries or change one's surroundings in the physical world. We have shown how XR and transness fit well together, because trans experiences often involve fluctuation and fluidity – elements that align with XR's ability to create hybrid digital/physical worlds. As XR evolves and reaches higher adoption levels, it holds great potential as a medium for innovative new technologies that can make real positive change in trans people's lives.

ACKNOWLEDGMENTS

We thank study participants for sharing their insights and experiences with us, and our anonymous reviewers for their constructive comments that improved this work. This work was supported by the National Science Foundation grant #2210841.

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A APPENDIX: INTERVIEWEES INCLUDED IN THIS PAPER

Received July 2023; revised January 2024; accepted March 2024

Table 2. Interviewees included in this paper. Most participants in this research explicitly wanted to be identified rather than anonymous, so we use their full names here, with permission. Other participants wanted us to use first names only, or pseudonyms, or wanted to remain anonymous. We report names based on participants' wishes in every case.

Name	Technology
Creators of XR trans technologies	
micha cárdenas	VR games and art (e.g., <i>Becoming Dragon, Sin Sol</i>)
Rob Eagle	<i>Through the Wardrobe</i> AR exhibition
Chitra Gopalakrishnan	<i>We Are All Made of Starstuff</i> AR exhibition
Irem Harnak	<i>Made This Way: Redefining Masculinity</i> VR film
Dylan Paré	Queer Code VR projects
Marte Roel	<i>Machine to Be Another</i> VR system, <i>Gender Swap</i> VR system
Evie Ruddy	<i>Queering the Creek</i> AR art exhibition
Dr. Nabeel Shakir	robot-assisted gender affirming surgeries
Creators of non-XR trans technologies who mentioned XR technologies in their interview	
Gaines Blasdel	top surgery nipple placement tool
Myra Lilith Day	art (e.g. <i>Femme Maison-1</i>)
Dev (Github creator d3v-null)	Jailbreak the Binary browser extension
GenderMeowster (they/them)	<i>GenderMeowster Podcast Network</i> ; <i>Genderful Talk Show</i>
Clairk Kronk	Transpedia; the Gender, Sex, and Sexual Orientation (GSSO) ontology
LemmaEOF	NameBlock browser extension; VTube streaming with robot avatar
Seanna Musgrave	games (e.g., <i>Dysforgiveness, Animal Massage</i>)
Tabitha Nikolai	games and art (e.g., <i>Ineffable Glossolalia, Sick Trans-Sex Gloria</i>)
K.J. Rawson	Digital Transgender Archive
Chris Vargas	Museum of Trans Hirstory & Art (MoTHA)