# *Situated VR: Toward a Congruent Hybrid Reality Without Experiential Artifacts*

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# Situated VR: Towards a Congruent Hybrid Reality without Experiential Artifacts

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***Abstract*—The vision of Extended Reality (XR) systems is living in a world where real and virtual elements seamlessly and contextually augment experiences of ourselves and the worlds we inhabit. While this integration promises exciting opportunities for the future of XR, it comes with the risk of experiential distortions and feelings of dissociation, especially related to virtual reality. When transitioning from a virtual world to the real, users report of experiential structures that linger on, as sort-of after images, causing disruptions in their daily life. In this work, we define these atypical experiences as *experiential artifacts* and present preliminary results from an informal survey conducted online with 76 VR users to highlight different types of artifacts and their durations. To avoid disruptions caused by these artifacts and simultaneously increase the user's sense of presence, we propose the idea of Situated VR, which blends the real and virtual in novel ways that can reduce incongruencies between the two worlds. We discuss the implications of experiential artifacts, and through examples from our own work in building hybrid experiences, we demonstrate the potential and relevance of Situated VR in the design of a future, more immersive, artifact free hybrid reality.**

**THERE** has been increasing excitement about the possibilities of Extended Reality (XR) systems (an umbrella term that covers virtual reality (VR), augmented reality (AR), mixed reality (MR), and other immersive systems) in the last decade with the introduction of several new consumer devices. Due to the COVID-19 pandemic, interest in XR systems has grown from 2020 to 2021 motivating the need for novel immersive systems that can support a diverse set of in-person interactions from work-related meetings to social gatherings and play [19]. An immersive future, as

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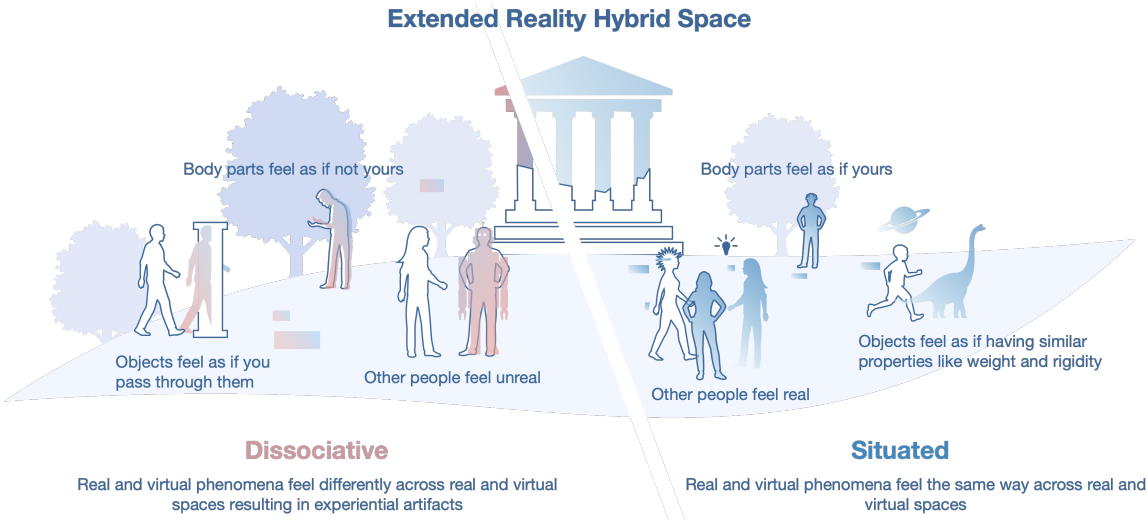


Figure 1: If we are to live permanently in a hybrid reality that consists of intertwined real and virtual elements, we need to create situated rather than dissociative experiences.

envisioned by many, involves living permanently in a connected hybrid reality with shared real and virtual elementswhere you spend most of your day, i.e., you put on your XR devices (e.g. glasses) in the morning when you wake up, and you take them off when you go to bed.

Different ideas of what an immersive reality might look like have been extensively represented in science fiction, where it is often portrayed as either a digital "jacked-in" space such as in Neal Stephenson's 1992 book, *Snow Crash*), or as a mixed hybrid reality space such as in Vernor Vinge's *Rainbows End*. Recently, big tech companies (e.g., Meta, Microsoft, Epic, Unity, Niantic, and more) have started to position themselves as Metaverse companies and share their own ideas of what a jacked-in, or hybrid reality space might look like. With this strong push, understanding the potential effects of such systems on human experience to ensure they are non-disruptive becomes increasingly important.

In this article, we envision a hybrid future where the digital and the real interact seamlessly in a continuum, reacting to each other in a constant exchange of information, allowing users to transition smoothly between the two. Regardless of whether a future hybrid reality is actualized as one of the Metaverses realized by big tech companies, or something entirely different, we believe, *inhabiting any kind of hybrid reality permanently requires users to feel situated* and not experience disruptions such as self- and world-dissociations caused by incongruencies between the virtual and the real.

A hybrid reality presents the potential to unlock many opportunities. For example, digital twins (or replicas) of cities can be simulated to model the behavior of millions, interactive AI (artificial intelligence) generated characters can step out of screens into classrooms, 3D holograms can enable interaction with friends and family on the other side of the globe, or sensor-laden devices can provide real time assistance and augmentation [10]. Building a hybrid reality could not only change the scale and scope of human computer interactivity, it could also create a new paradigm shift in what our understanding of realityis: It could be a place where both real and virtual humans, entities,and elements (e.g. objects, AI generated characters, virtual people, places) are seamlessly intertwined. As this shift might significantly change human perception, experience and understanding of the world, making this shift requires not only careful design but also a high level of responsibility, active questioning and investigation into the first-person experience of living in such a world.

There are several challenges related to the design of systems and experiences that hinder our ability to live in a fully hybrid reality. We are currently spending considerably less time using VR systems than envisioned: in 2019 the average

session time of VR users in the United States was just 19.7 minutes [29]. One predominant challenge is the undesirable discomfort or cybersickness that can accompany VR experiences, reducing their appeal and minimizing the user's sense of presence [32].

While researchers have suggested that cybersickness related symptoms of nausea, dizziness, disorientation and fatigue are likely to be resolved over time with better hardware [15], we would like to highlight another challenge that we have first observed through our own experience with VR systems, and which we consider equally relevant and necessary to resolve for the future.

By surveying 76 VR users online, we confirmed the occurrence of what people report as strange feelings about their own body and things around them that linger after coming out of virtual experiences. We call these feelings *experiential artifacts* (EAs) and, as we will show, these EAs present themselves as changes in a user's perception of things and experience of themselves,and are particularly noticeable when transitioning between the real and virtual worlds. These artifacts can be characterized as atypical experiences of body boundaries, objects and other persons, and are sometimes associated feelings of body and reality dissociation: some users, for instance, report feeling as if their body parts are not theirs, as if they can pass through objects, or as if other people are fake. Similar self- and world estrangementsare also found with other on-body technologies like brain-computer interfaces (BCIs) where they are known to negatively impact a persons ability to function, reduce their desire to use a technology, and in some cases lead to mental distress and self-harm [6].

To go beyond the challenges of EAs and effectively realize the vision of living in a hybrid reality, we propose the idea of Situated VR and define it as an approach to the design of VR technologies with the aim to create congruent experiences of phenomena across real and virtual worlds, that can potentially allow us to avoid EAs. Our definition differs from prior work where "situated" has been used to refer to a physical location where user and object tracking are supported in a VR application [31] or interaction with people and objects "situated" in their physical space is supported without losing the sense of presence [7]. To further differentiate our meaning of the term Situated VR, we introduce the complementary term "sense of situatedness" that refers to the consistent and non-disruptive experience of self, world and social phenomena when using XR-systems. We introduce this term to highlight the importance of making non-disruptive structures of experience across real and virtual worlds a primary design goal for hybrid reality engineers rather than the one-to-one replication of physical structures (e.g. material properties such as form, shape, size etc.). We believe that this shift in focus is necessary to realize the envisioned *hybrid reality* as a tight and seamless integration of the virtual and real without experiential artifacts.

## Experiential Artifacts

The experiences of ourselves, our surroundings and others are formed through a complex interplay between multisensory signals, and internal mappings of the world and self. As neuroscientific research has consistently shown, experience does not present itself as an unfiltered, precise image of the world. Rather, it involves variability of how things are presented and is afforded by not just bottom-up sensory inputs but also top-down processing dictated by our attentional focus and internal mappings (or cognitive models) of our body and the world [30]. In the rubber hand illusion, for instance, multisensory stimulation can make participants feel as if they have a rubber hand - but only as long as it bears some resemblance to their internal map of their body [27]. An important feature of these internal mappings is they are partly constructed by previous experiences with objects and people in our daily life and can thus be altered through repeated exposure to newer or even unnatural bodily and world experiences.

In the Innsbruck Goggle experiments, for instance, researchers inverted participants' retinal image through an optical apparatus. These alterations were shown to create, first, an unfamiliar and distorted experience of the world (e.g. seeing the world upside-down). But, after a few weeks, the upside-down orientation of the world became normalized (e.g. they no longer saw the world as upside-down). Following normalization, removing the apparatus again caused participants' experience of the world to become distorted (e.g.

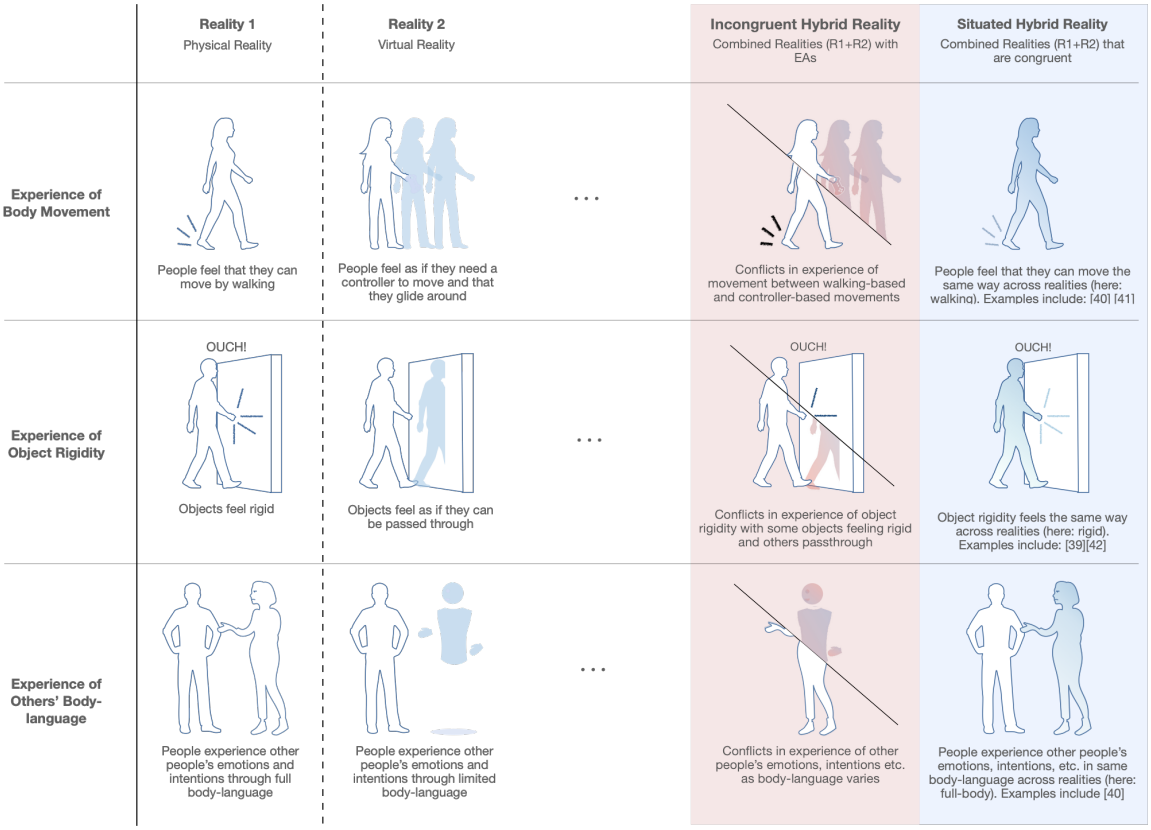


Figure 2: Examples of Experiential Structures in separate and hybrid realities

the world again appeared inverted despite glasses not being worn anymore) [16]. These examples demonstrate how internal mappings of world and self can be altered, and that when they are altered they can create atypical or anomalous experiences, which can become the new normal.

These atypical or anomalous experiences can be found in various disorders. For instance, autism spectrum disorders have been characterized by atypicalities in the experience of chromatic stimuli, isolated tones, coherently moving dots and complex objects, as well as social stimuli, including faces, eye-gaze direction, perception of motion, and speech [14]. Similarly, schizophrenia spectrum disorders have been characterized by anomalies in the experience of self, body-boundaries, and worldly objects [18], [17]. Schizophrenia patients will, for instance, claim that they feel like their body "[does] not hang together" [18], that "things [around them] do not feel real," or that they experience "other people as robots" [17].

In this article, we suggest that similar disorganizations of experience can be found among some VR users in the form of EAs. We report EAs of current systems to typically include feelings of altered body-boundaries, objects or other people, and dissociation with oneself and reality.

## Experiential Artifacts Survey

In order to get a preliminary understanding of the types of EAs one might experience with current VR systems, we conducted an informal survey that was posted onVR subreddits[1] for one day and received 76 unique responses. Of the 76 responses, 40 participants submitted extended descriptions of the EAs they experienced. The responses include EAs experienced after being in specific VR applications (e.g. Half-Life: Alyx, or Superhot), and thus these responses do not cover all types of VR experiences currently available. Further, not all participants disclosed the applications after which they felt EAs. Note that in this introductory article on EAs, we do not go into

[1] www.reddit.com/r/virtualreality, www.reddit.com/r/oculus, www.reddit.com/r/oculusquest, www.reddit.com/r/vrchat

the specifics of which aspect of a VR experience caused a particular EA but plan on exploring that mapping in future work. In the survey we asked:

1) "Have you ever had an experience of your self, body, objects, or people in your environment feel strange or somewhat different after coming out of a VR / AR session?"
2) If yes, "What happened and how did you feel?"
3) "How long did it last after the session?"

Based on survey responses, we found that altered feelings of one's body, objects, reality, and other people lingered after a VR session for many of those who responded (above 56% of 76 participants[2]), with the strongest effects occurring when users are new to the devices and experiences. After sessions of over one hour in length, participants reported EAs that lasted anywhere from 1 hour to 5 days.

**Bodily Feelings** In the survey, one of the most reported experiential anomalies involved atypical feeling of users' bodies, especially hands (58% of 40 participants who submitted extended descriptions). These responses included reports about body parts not feeling as their own anymore; and that users did not feel linked to their own body. Participants reported experiences like, "I feel like my hands were not my hands", "You feel like you're gliding on the world rather than walking", or that they feel "taller" after coming out of a session. One participant stated that "[...] when I first started playing VR, I would feel like my hands were not my hands or for a moment things would feel as if I could pass through them" with the experience being "sort of like you're floating out of your body when looking at it.".

As stated, these atypical bodily feelings were typically centered around users' hands, which in current systems are the primary mechanism of interacting with the virtual environment. As full body avatars become increasingly a part of consumer VR experiences and people's virtual bodies and bodily interactions begin to include more than just hands, it is possible that these anomalous feelings may extend from the hands to the entire body depending on how the virtual body is "used" in the virtual world (e.g., being able to kick things, having increased body-haptics, being in a non-humanoid body, or having the body animated.).

**Object Feelings** Participants also reported objects to feel different. Real objects they would hold or sit on would feel "floaty", "weightless", and as if one "could pass through them". One participant, for instance, had a feeling as if they "could walk through doors without opening them", while another "took objects out of the cabinet and was surprised that cans had weight and noticeable shifting liquids in them", and sometimes "didn't feel [themselves] holding the thing, [as if] it was basically weightless".

Based on the goal of haptic feedback devices to create more realistic VR experiences [9], [28], it is possible that as a larger variety of haptic feedback is integrated into consumer experiences, or passive- and pseudo-haptics become more employed, the experiences of virtual objects may start to become similar to those in the real world. For example, the popular VR game Half Life: Alyx employs sloshing sounds, liquid that appears to react when a bottle is shaken and clever rendering to make the experience similar to shaking a real bottle, even though the player cannot feel the weight, temperature, texture and other characteristics of the bottle. This introduces an experience of pseudo-haptic feedback which aims to increase the object's behavioral match with its real world counterpart without necessary copying its physical shape and properties completely, and consequently, match the experience of interacting with it to enhance the user's sense of presence in VR.

**Interpersonal Feelings** Some participants reported their feelings of other people to change as well (23% of 40 participants who submitted extended descriptions). They would, for instance, feel as if people "gazed at them differently", "had different body language", or weren't real people. One participant reported that, "people looked like they were NPCs (non-playable characters; programmed/artificial) from [their] point of view, [and] conversations seemed lacking of content". Further, social interactions were also affected

[2]Since the responses came from a self-selected group of individuals, the actual prevalence of EAs in the broader VR user community is harder to gauge from this survey.

for some participants: “when I was talking to someone [in real life] I looked up to see what their username was. I’ve also tried to walk through people [in real life].”

**Dissociation** A typical property of these anomalous bodily, object and interpersonal feelings reported by the survey respondents was the feeling of dissociation from themselves and/or reality. For most participants (33% of 40 participants who submitted extended descriptions), EAs were associated with a feeling that their body or things around them were not real, that “everything feels fake”, and that they were disconnected from the world, merely “watching it go on from the outside”. For instance, one participant reported that he “kept looking at [his] hand to check if it was real or not”:

> I just didn’t feel real in real life [...] Sometimes I’d wake up in the middle of the night and just spend several minutes staring at my hands wondering if they were real”.

For another respondent, they felt as if their

> “body was being ’disconnected’, and just floating there, also when holding an object, eg. my phone, it felt like it’s just floating. Also had busy dreams/half asleep moments when I felt confused whether I’m in the real world or not.”

While these experiences of dissociation might sound bleak and unpleasant, many of those who experienced EAs for shorter periods, found them interesting and were sad when they went away. On the other hand, some participants, who experienced EAs for longer periods, reported that they could “make life a little harder” and expressed positive sentiments when they went away. Some were even hesitant to return to using VR since they feared EAs would linger for longer periods after use. These mixed responses hint at greater harm with an increase in EA duration though what impacts the duration of EAs and if there are interpersonal differences remains to be explored. Common across most participants was, however, the sentiment that EAs were temporary and mostly occurred for those new to VR or after upgrading to a more immersive VR system. However, one participant reported spending 7 hours in Beat Saber before feeling EAs for a week - “I felt like my body wasn’t my own. I would move but it just felt like I was on autopilot. It was like I was watching the world go on”. Another participant spent 5-10 hours over 2-3 days in Echo Arena where the EA lasted for 4-5 days - “My hands felt as though they were not my own and I was still in VR even though I wasn’t”. In general, most participants reported that EAs typically lasted anywhere from 1 hour to 5 days though not enough participants specified time spent in VR to allow us to correlate it with EA duration.

The EAs were reported as mostly harmless and they disappeared after a short amount of time. However, it is unclear how they will develop as we start spending more time in ever more immersive VR and a future hybrid reality. Research has, for instance, shown that integrating technology on or in the body for longer periods can induce strong feelings of alienation/depersonalization, anxiety and stress leading to reduced use, device abandonment, and in some cases even suicide [5], [6]. This was reflected in the survey response of one participant, who stated to be a frequent long session VR user:

> “I often feel intense depersonalization after leaving VR. Over time I’ve built up a kind of disconnect between the physical ’me’ and my conception of ’me’. In VR, you can change your bodily appearance like we would normally change clothes. You learn to identify yourself and other people by their names, voices, and behavior much more than by what they look like. That idea has leaked into my reality, in a way. When I’m fresh out of VR, I don’t identify with my body, it just happens to be the way I look at the moment. The real ’me’ is all in my head, and always will be, no matter how I look. The common comparisons of ’feeling as if you’re watching your life play by on a screen’ or ’feeling like you’re just controlling a robot’ you normally hear from sufferers of depersonalization and derealization disorders are apt descriptions of how it feels to me.”

This exemplifies a potential challenge for the design of future VR systems. If we are to realize the vision of integrating VR more deeply into our daily lives and live in a hybrid reality, we must consider not only technical constraints but also experiential impacts. While we suspect nausea and similar symptoms induced by VR systems to eventually be resolved with better hardware and a broader spectrum of sensory input, EAs present different challenges. Rather than hardware, EAs seem to depend — similar to effects of the Innsbruck Goggle experiment — on the experiential structures afforded by the sensory input of the VR system in congruency with the internal body and world models of the user.

**Hybrid Reality and Experiential Incongruencies** As reported by participants, the type of EA one experienced typically reflected the VR application they had been in. For example, participants reported time felt slower after coming out of games where one could control time, or that they felt like they had to press a button to move in the real world after playing games where locomotion was bound to a controller.

> "Walking is an odd sensation, felt like I needed to use the controller to walk."

Similarly, another participant reported that they felt like they were "still in [the video game] Half-Life: Alyx and [...] tried flicking things to [their] hands [in real life]" (In the game, a player can flick their wrist to pull non-proximal objects towards themselves instead of picking them up).

Based on these reports, we expect EAs to arise when transitioning from any reality to another, not just from the virtual to the real. For instance, when playing Half Life: Alyx for the first time, pulling items towards you with a flick of the wrist feels strange because things do not just fly at you in the real world, you have to go pick them up. Quite quickly, you adjust to this superpower and even relish it. After transitioning back to the real world, the expectation of the superpower working continues but is unmatched by reality, leading to cognitive dissonance, an EA, and a subsequent feeling of dissociation. Similar to inversions of the retinal image [16], we suspect this to be caused by internal models of the body and world that are adapted to one type of body and world, and, when transitioning to a new/different world or body, need to be rapidly updated to match the new phenomena, otherwise the incongruency with the adapted body model results in EAs.

While the EAs of current systems are mostly temporary and go away after the user spends more time in VR, it is unclear whether this will also be the case in a more immersive hybrid reality in the future. For instance, if a hybrid reality is to consist of different experiences offered by, for example, different companies [13] similar to how we have different apps on our smartphones, and they all require different cognitive models, it is not guaranteed that enough neural resources are available for such rapid adaption [4] as we transitions between them and the real world. In fact, as has been shown in recent research, the plasticity of internal cognitive models can be rather limited. In the rubber hand illusion, for instance, the embodiment of the rubber hand is typically followed by a disembodiment of the real hand [11]. After the experiment has ended, participants often report their real hand to feel as if it is "not there" or forgotten [11]. Therefore, if we are to live in a hybrid reality without disruptive and dissociative EAs, we must avoid incongruencies in experience across the different realities and help the user smoothly transition from one immersive experience to another.

## Situated VR

In this work, we have defined Situated VR in terms of experiential structures, such as a sense of self, sense of agency, and expectations of worldly phenomena (e.g., sense of time, object weight or rigidity) that are congruent as one transitions between the real and the virtual worlds. Since EAs are caused by incongruencies between the real and the virtual, Situated VR presents one possible way to help mitigate EAs.

Authors have argued that the "sense of embodiment" plays a critical role in influencing the user's sense of being in a virtual environment [25]. According to Kilteni, Groten & Slater, the sense of embodiment is the "experience [of] our self as being inside a body and more specifically a body that feels 'ours', which moves according to our intentions, obeying our will." [8]. However, as shown by our survey, the experiential disruptions that impact users are not just confined to bodily experience but are also environmentally and in-

terpersonally determined. Therefore, while other researchers have focused on experiential notions like avatar-based "embodiment" in VR, Situated VR focuses on the design of experiences that "feel" similar, in both the real and the virtual world, so as to provide the user experiential congruency. We believe this can help mitigate EAs which we hypothesize to be caused by incongruent experiences of our body, objects and others as we transition from one reality to the other.

To be situated in a VR context means that one "feels" grounded in the virtual world and virtual self that one inhabits socially, environmentally and bodily. It means the experiences of real and virtual worlds broadly match the user's expectations and typical experience of things without the virtual needing to replicate the real in all aspects (e.g., texture, actual shape, material etc.). As demonstrated in the previous section and as shown in Figure 2, this includes — among other things — body movement, object rigidity, and the body-language of others, which can be experienced differently between real and virtual worlds and cause EAs. Therefore, as an extension of recent work in cognitive science [3], we posit that our feeling of being situated is not just constituted by social, environmental and bodily factors but also how these factors are continuously altered and varied as one moves between real and virtual worlds. Altering how objects weigh, or how they respond to being pushed, for instance, from one reality to another creates a discrepancy that situated VR attempts to avoid. Practically, this translates into designing VR systems that, within certain limits, must afford congruent experiences where the physical space, tangibility of objects and user agency is meaningfully reflected. These can be achieved by matching user expectations such as object permanence and rigidity, bodily location in space, flow of time, social norms, or proxemics.

Since contemporary VR systems only target specific sensory modalities, our experiences of ourselves, things and others in virtual worlds are never completely virtual. Rather, our experiences occur with a mix of sensory information from both the VR system (typically visual, auditory, or haptic), our body (e.g., proprioception, interoception, thermoreception), and its interaction with its environment (e.g., touch, equilibrioception, gustation, olfaction). This discrepancy has been highlighted as a pressing challenge for the design of VR systems [26]. However, VR systems are also challenged by another discrepancy which is one of experiential structures between real and virtual worlds. As described above, this includes changes in how objects are expected to feel (heavy, light, rigid), where one's body is located in space, how time progresses (slow-motion, with the movements of the user), and how other agents socially express themselves and interact. Such discrepancies or incongruent structures of experience that cause EAs can be mitigated by designing situated VR experiences where the real and the virtual are more deeply connected.

Our survey results show that EAs are caused by many different kinds of incongruencies. For example, we observe some EAs to be caused by incongruent body-movement (controller vs legs), object rigidity (pass through vs solid), and interpersonal body-language (pose and expression) between the real and virtual worlds. In order to show how one might mitigate individual EAs to elicit a sense of situatedness, we will in the following paragraphs of this article consider how to approach these three specific example cases of non-situatedness of experiences and make them situated.

Situated body-movement can, for instance, be enabled by connecting the affordances of locomotion in the real space with those of the virtual (e.g., natural walking in the real and virtual worlds simultaneously). Situatedness of object rigidity can be enabled by making sure objects respond similarly to physics or interaction in real and virtual spaces (e.g., by objects pushing your hand back when being touched rather than passing through). Situatedness of other people's body language can similarly be enabled by having emotions and intentions be expressed with the same body language in real and virtual spaces (e.g., through complex full body language such as posture and facial expressions, or simple body language through visually expressive avatars [1]). Including these elements in the design of situated VR experiences can reduce feelings of disconnection (opposite of presence) with oneself and the environment [12].


Figure 3: Figure shows examples from our prior work and how they may help resolve EAs. Top row: Oasis[22], [21] automatically creates a VR world using the real world as a template to enable walking. Middle row: 3D scanning and tracking a chair in realtime allows VR users to sit in a real chair in Oasis. Bottom row: In Your Place and Mine [24], two remotely located users can dance together in VR as if they are in the same physical space.

In the next section, we present how one might attain congruency between real and virtual spaces through some of our prior work as well as explore the relationship between the self and the currently inhabited reality, virtual or not.

## Prototyping a Situated Hybrid Reality

To better understand what a future hybrid reality might feel like, we have worked on creating a series of working prototypes, some of which we present here. These prototypes showcase different aspects of situatedness through a congruent connection between the real and the virtual whether it is the user's experience of space, locomotion, objects or the body.

In Oasis, we built an automated world mapping system that generates multiple virtual spaces corresponding to a given physical space [22], [21]. To avoid incongruencies between real and virtual body movement, the affordance of walkability is maintained such that a user can walk in their home or work environment while walking the same paths in a visually different virtual world without walking through or into objects (Figure 3). Despite the visual differences (e.g., a dining table may be represented as a pool of water or a large rock), the situated walking experience creates a congruent sense of spatial match across the worlds that is felt through the body in motion. Other similar works include VRoamer [2] and Dreamwalker [33] that explore dynamic and outdoor path planning to overlay a virtual experience on the real world that supports natural walking.

Our project MoveU [23] presents a way to obtain sensory congruence of bodily movement,


Figure 4: Left: The MoveU device as worn by a VR users with electrodes connected behind each ear for electrically stimulating the inner ear using galvanic vestibular stimulation (GVS). Right a,b): MoveU used in a VR roller coaster and VR car driving experience to match the sensory perception of riding a coaster and a car by stimulating the inner ear during turns.

as demonstrated through a virtual roller coaster experience (Figure 4). The physical user, seated in a chair at home matches the sitting position of a roller coaster rider, unlike many VR experiences where the user's body pose does not match the virtual activity e.g., physically standing while virtually walking or physically sitting while virtually flying. The visuals and sound effects match the real ride, though including other riders would make the match stronger, especially since the social aspects are a big part of the ride experience. With a wearable galvanic vestibular stimulation system (GVS), MoveU makes users feel the coaster's twists and turns in their inner ear, just as they would feel them on a real roller coaster. Stimulating the inner ear programmatically as it would be stimulated on a real coaster is different from providing haptic feedback in VR experiences which is often done through vibrotactile feedback that serves as a proxy for the real tactile sensations. By adding crucial inner ear stimulation, not only do we create a closer match with reality, we also mitigate symptoms of nausea or cybersickness.

As an example of congruence of body language, we explored integrating physical spaces and bodies of remotely located users in *Your Place and Mine*, a VR experience that generates a shared virtual space where two remotely located users can both move around one another as if in the same room [24]. We chose dancing as our example use case for since it is a natural shared exploration of physical space (Figure 3). The goal was to find intersections based on each user's physical space (e.g., one user has a 2x2m space while another has a 4x4m space) to create a shared virtual space where both users can freely move and dance together. In the study, we found that scaling or increasing the movement of one person's body caused a lower sense of co-presence and togetherness with other people. In contrast, sharing a virtual space with the appropriate mapping techniques that resulted in normal and un-scaled body movement was reported to be more expressive leading to a higher sense of togetherness and co-presence.

Passive haptics is another way of achieving congruency in the experience of objects. Flexibility and creative freedom in the design of VR applications can be achieved through increasing the mismatch between the haptic proxy and the virtual object without adversely impacting the user's experience. For example, in Substitutional Reality, Simeone et al. [20] create virtual objects to approximate the haptic properties of one or more physical objects as felt by the user's hands. They explore a wide range of proxies from those with a 1:1 match between the virtual and the physical objects to those with greater mismatch between the two through alteration of appearance (addition/removal of details), changes in functional affordances (e.g., a book with a box) and categorical substitution where the physical proxy has little to no resemblance to the virtual object is stands in for. We explored a related substitution in Oasis [22], [21] for providing haptic feedback to the user's full body with a physical chair that is detected and tracked in real-time, allowing the user to sit in its virtual counterpart as they explore their automatically generated virtual world. The virtual chair retains the affordance of sitting but visually and functionally does not match the physical chair (e.g., missing arm rests, missing casters, different material, color and texture, dif-

ferent height, seat size and back rest). These changes did not alter the affordance of ''sittability'' or the user's perception of the virtual chair and thereby successfully maintained congruency of the sitting experience.

Although not yet empirically validated, these examples show how Situated VR may have the potential to mitigate EAs through the design of experiences that match user expectations and provide a congruent experience. Since systematically understanding EAs is new research piloted in this article, we believe that the Situated VR examples presented above are likely to mitigate specific EAs due to their ability to minimize incongruencies between the real and virtual worlds. Ideally, when a user transitions between worlds, artifacts from one world should not follow them into the other, as those are the primary cause of feelings of dissociation and unreality. While current EAs are temporary, as we begin to spend more time in a hybrid reality with continuous transitions between different immersive applications and the real world, there is greater potential for longer lasting EAs and consequent adverse impact on a user's mental health and wellbeing. Therefore, future work on VR should seek to methodically understand these EAs, their causes, and evaluate what techniques could be used to create congruent situated experiences.

## Limitations of a Situated Reality

While achieving experiential congruence through situatedness can help reduce EAs and create experiences with a high sense of presence, one could argue that if an experience is the same as the real thing, it could present its own downsides by leading to confusion about what is real and what is virtual. One extreme example of this is the science fiction film The Matrix[3]. In the film, the virtual is experienced with such verisimilitude to reality that most people are unable to tell them apart.

On the other hand, given the limitations of current technologies, one could also argue that regardless of "realism" of experience, if VR becomes a deeply integrated part of our daily lives, much like our current online lives accessed via multiple devices (smartphones, smart watches, smart speakers), the new hybrid reality will become too meaningful to us to not be regarded as real. It is possible that this integration may initially cause some confusion depending on the degree of congruency but may eventually become normalized similar to the Innsbruck experiments. Therefore, as we improve technology, we need to question whether we want to build and live in a hybrid reality with complete congruency between the real and virtual.

We believe there is a fine line between creating a real/virtual match (sensory information, body/world models, object behaviors), reducing EAs, taking advantage of VR's own unique affordances, and avoiding building The Matrix. As we start to build our future hybrid reality where we may spend much of our daily time, aiming for situatedness does not exclude designing unique and different experiences that are physically impossible such as flying, teleporting or wandering through non-Euclidean worlds, where experiential structures such as body-boundaries, object rigidity or time are altered. Rather, non-congruent experiences can be interesting and fun as long as they are temporary — but not if they are permanent (as also reflected in our survey reports). For instance, consider wearing goggles that mirror ones vision for just a few minutes, and compare that to putting them on and taking them off repeatedly. In the first case, it might be fun for a while, while in the latter, it would be unpleasant as the user would constantly have to adapt back and forth leading to high cognitive load and sensory dissonance.

## Looking to the Future

The current state of VR systems offers fragmented, isolated experiences with great variability in experiential structures across locomotion, interactivity, rigidity of objects, perception, movement, shapes of virtual bodies, expressiveness, language and so on. At the moment, each VR experience is its own closed system that one has to exit to enter another, rather than being a permanent, always-on type of reality that is tied to contextual elements of the real world, that, for instance, enable you to visually bring a real water bottle into your virtual game world, or have your virtual office fit to elements of your home office. As VR technologies and the idea of a

[3]https://en.wikipedia.org/wiki/The_Matrix

Metaverse continue to develop, we expect to see not only greater adoption of the technology and inclusion of sensory modalities, but also a hybrid reality emerge that consistently and seamlessly integrates real and virtual elements and spaces into a unified, situated experience.

For a hybrid reality, where you may spend most of your day to work, play and socialize, we do not want EAs and dissociation to be a continuous part of the user's daily experience. To improve current devices for a more immersive and less disruptive hybrid future, one goal of current VR systems for many researchers is to make them align with the physical reality [22], [2], [33]. More specifically, by building systems that deliver sensory feedback where properties of virtual objects align with the laws of physics, they believe we will be able to go beyond challenges of current systems and deliver more immersive experiences. In contrast, we believe that situatedness rather than replication of reality should be the primary goal when designing future systems. Unlike replicating the real, situatedness does not constrain the virtual to the physical properties of things. Rather, by focusing on experience and its congruence between the real and virtual, situatedness allows for reality defying applications and self-expression, while still ensuring such experiences are safe and non-disruptive.

Based on the research presented in this article, we believe feelings of disconnectedness in VR systems, such as EAs, are not caused by a lack of physical properties in the virtual space but rather by how the brain and body map worldly and self phenomena in one space and transfer those mappings to another. If dissociation is caused by incongruent experience of body-boundaries, objects, and other persons due to conflicting internal mappings of self and worldly phenomena, then the goal should not be to mimic physical properties of things in virtual spaces but rather to keep the experience of things generally *consistent* across virtual and non-virtual spaces. Essentially, this means that either VR spaces and elements experienced similarly to reality, or real spaces, modified to be experienced similar to VR spaces [26] could create situated experiences — e.g. through the use of passive haptics or pseudo-sensations. As VR technology continues to develop and we move towards living in a hybrid reality, greater consideration of how experience of self, objects and other people can be consistent across realities is an important, if not necessary, step for its success.

The anomalies, once assimilated, may in some cases no longer be unusual and could instead become part of a user's reality, just like the goggle induced inversions of the retinal image in the Innsbruck experiment [16]. Thus, this poses an interesting question about the role of time on experiential artifacts, and whether EAs are just temporary artifacts caused by recent transitions or adaptations between different modes of reality, or whether they could end up being a constant cause of experiential disruptions for individuals. Future work on EAs should seek to:

- Explore changes of EAs over time and their impact on the bodily, object, and social experience of real and virtual worlds.
- Categorize types and estimate prevalence of EAs.
- Investigate whether EAs occur in other XR modalities like AR or MR or are mostly confined to VR.
- Find and evaluate ways to design experiences that can help mitigate EAs.
- Consider changing design goals from replicating reality to creating a greater sense of situatedness that is more about creating a congruent experience than about matching physical laws and real world fidelity.

For centuries, magicians, artists, writers and others have explored the subjective nature of perception. As argued in this paper, a future hybrid reality will be a blend of the real and virtual where things feel coherent and the transitions feel seamless and free of experiential artifacts. Creating this future will require researchers and industries to interact and imagine new possibilities, understand the burdens of responsibility and ask the big questions, about how life in a hybrid reality can provide new opportunities and help transform individuals and society for the better. A first step towards this is taking the technology and its influence on the structures of experience seriously.

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