The Dream is Collapsing: The Experience of Exiting VR

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ABSTRACT
Research on virtual reality (VR) has studied users' experience of immersion, presence, simulator sickness, and learning effects. However, the momentary experience of exiting VR and transitioning back to the real-world is not well understood. Do users become self-conscious of their actions upon exit? Are users nervous of their surroundings? Using explicitation interviews, we explore the *moment of exit* from VR across four applications. Analysis of the interviews reveals five components of experience: space, control, sociality, time, and sensory adaptation. Participants described spatial disorientation, for example, regardless of the complexity of the VR scene. Participants also described a window across which they exit VR, for example mentally first and then physically. We present six designs for easing or heightening the exit experience, as described by the participants. Based on these findings, we further discuss the 'moment of exit' as an opportunity for designing engaging and enhanced VR experiences.

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H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
Virtual Reality (VR) is being employed to provide a wide range of experiences. Recent advances in commercial VR headsets have led to new industry attention on VR games. In research, VR has a long tradition as a tool for studying complex phenomena (different perspectives and fears) [26] and, increasingly, as a technology for exploring novel experiences [7,9] and collaborations [18].

While the user is in VR, the user experience is well understood. Research has explored both the technical factors of immersion (e.g., [11,39]) and the experiential factors of presence (e.g., [36]). After exit, the mid-term aftereffects of VR have also been explored [1,38], such as through simulator sickness questionnaires [22]. As VR has long been used as a learning tool [10,31,43] and a means of combatting phobias [26], the long-term effects of VR are similarly well explored. For example, studies have shown that VR training can improve precision in laparoscopic surgery [23] and decrease indicators of arachnophobia [10].

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Across these VR experiences, however, the act of entering and exiting VR – the very moment of donning or doffing the headset – plays an important role in the overall user experience, but receives little attention. At CHI 2016, Azmandian et al. [3] presented a paper on haptic retargeting in VR, where the participant physically interacted with three virtual boxes, all represented by a single real box. Anecdotally, the authors suggested that, across many participants, removing the headset resulted in a 'Holy S***' moment, when the participants realized they had been subject to an illusion. This sudden realization, or collapse of experience, demonstrates that the 'moment of exit' may be an untapped opportunity for shaping user experience in VR.

Designing for the moment of exit could be used to many ends. First, designers could choose to lessen any surprise in removing the headset by making the user aware of any changes in the real environment whilst they are in VR. For example, a VR application could adapt to the fading light in reality or provide see-through glimpses of people entering the room. Conversely, in a multi-user VR setup, gamified exit moments (where a player creates exit experiences for another) could be used to heighten the social experience. To date, the experience of VR has been solely bound within the VR headset, but the moment of exit may present an opportunity to challenge that binary boundary.

In this paper, we focus on this moment of exit – as the VR 'dream' collapses. We use the phenomenologically inspired explicitation interview [28,42], as a launch point to understand the user experience of this moment. Participants each take part in one of four VR scenarios, covering both commercial and research applications of VR, including gaming, illusions, perception warping, and cognitive tasks. Upon exiting each experience, participants are interviewed. Using thematic analysis, we highlight five themes across space, control, time, sociality, and sensory adaptation. Participants were also asked to speculate about design opportunities to heighten or lessen the experience of exiting VR. We sketch and discuss these designs. We present the concept of a moment of exit when leaving VR and detail its experiential features. The moment of exit opens new opportunities for designing VR experiences that exploit the boundaries between the virtual and real worlds.

RELATED WORK

The literature on VR has explored both being in VR, as captured by presence, and the mid- to long-term effects of leaving VR. To date there is a gap in our understanding of VR experiences during the moment of exiting VR – between the experience of presence in VR, and the onset of VR aftereffects. Here, we discuss the broader literature on experiencing VR that motivates our work.

What's it like in VR?

Previous literature has considered many measures of experience in VR. Typically, these focus on immersion and presence. Immersion is an objective measure of the technical performance of the system – its ability to accurately portray a reality [37]. While this has an impact on user experience, it can be measured without any user input, and focuses on frame rate, resolution, tracking, and so on [29]. Presence, our main interest here, is the subjective measure of experience. Presence concerns either (a) the extent to which the participant believes themselves to 'be there' within the reality of the VR [35], or (b) the extent to which the environment successfully supports action [12,46].

Across the literature, presence is explored in different ways, including post-experience questionnaires and interviews (e.g., [41,44]), continuous rating scales [32], and user behaviors [14,25]. These different metrics uncover a variety of different experiences.

Typical immersion questionnaires ask about 'being there' in the virtual environment – the extent to which the virtual felt more like the current reality than the real world, and whether users in the virtual environment felt like they were visiting somewhere or simply seeing photographs [29]. Questionnaires also cover the complexity and naturalness of achieving certain tasks in VR [36], control [44], involvement, and predictability [30]. (These factors of presence are also explored for presence in non-VR experiences [40]).

When 'there' in VR, participants may replicate real-world behaviours in response to virtual phenomena. For example, Meehan et al. [25] found that users would take longer paths when walking in order to avoid virtual obstacles, Slater et al. [34] examined correlations between a 'ducking response' to fast-moving virtual objects and presence, and Freeman et al. [14] observed postural swaying when in VR. Any use of these movements would serve to indicate that the user is 'there' within the virtual reality.

When fully engaged in VR, users should experience a diminished sense of their real environments [32]. During the ongoing experience, however, this engagement may be briefly broken, for example by a momentary drop in frame rate, or a loud noise from the real environment, causing the user to temporarily transition back to awareness of the real world. Previously, this has been explored as a break in the experience of presence. Slater et al. [32] asked participants to self-report the in-experience transitions from virtual-immersion to reality (i.e., the moments when the virtual immersion broke down and they became once again conscious of the real world around them). These breakdowns may provide a similar insight into the experience of virtual-to-reality transitions, but in these instances the user then continues to use the VR system – attempting to stray back in to the virtuality. We look at these transitions during the final exit of the virtual environment. This allows us to gain an in-depth insight into user's experience of transitioning from virtual-to-reality.

What's it like back out of VR?

Previous literature has also explored the aftereffects of virtual reality – the aspects of the experience of VR that persist beyond use. To date, these explorations have predominantly focused on mid-to-long term effects. We define mid-term aftereffects as those that may continue over a matter of minutes (or hours, in the extreme), but have no lasting impact on user behavior. Long term effects include learning effects and behavior adaptations.

A popular method for exploring mid-term aftereffects is a Simulator Sickness Questionnaire [22]. Although these focus on nausea and other sickness related phenomena, they also include issues with proprioception and psychological factors (including anxiety, apathy, and depression). These phenomena, especially those of anxiety and proprioception, may be especially relevant to the moment of exit in VR. For example, should the VR scenario make use of proprioceptive illusions (such as [3]), any lingering proprioceptive dissociation becomes apparent and is immediately corrected upon leaving VR. Similarly, a reflective anxiety on who was watching you in VR may come to the fore upon conscious thoughts of reality.

Long-term aftereffects have also been a focus of virtual reality research. A large body of research exists on using VR as an educative tool – examples include teaching doctors surgery techniques [23] and training new pilots [43]. In these instances, the learning effect of VR exposure is studied over time. For example, a meta-analysis of surgical training found that VR training did reduce surgery time and error rate [19].

Another body of research examines the use of VR to change user perception, whether regarding fears (e.g., [26]) or personal viewpoints [4,45]. In a VR arachnophobia study, for example, 83% of participants achieved a clinically significant improvement of their phobic severity, two weeks after their VR treatment.

In one example of literature exploring the moment of exit, Slater et al. [33] considered surprise when exiting VR. They found that participants' surprise at discrepancies between similar real- and virtual- environments increased with their presence in distractor tasks. Alongside this, and more relevant here, Slater et al. report that entry into, and exit

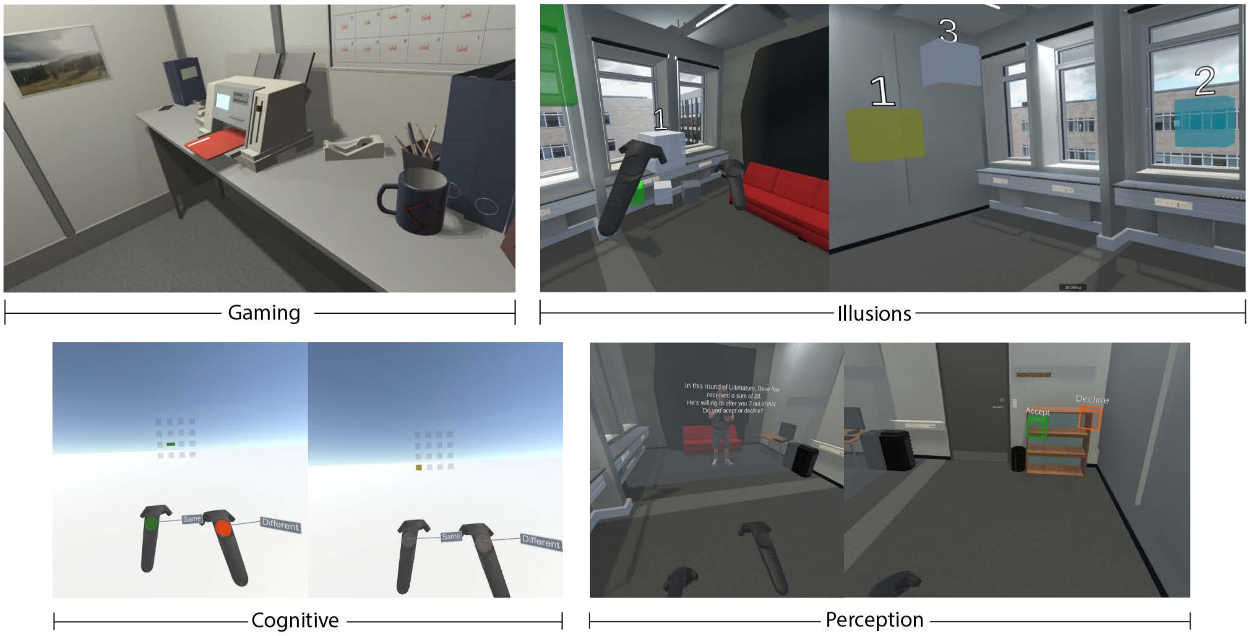

Figure 1. The four VR scenarios. Top: Gaming and Illusions scenarios. Bottom: Cognitive and Perception scenarios.

from, similar virtual and real environments (the same laboratory in their case) offers a 'gentle transition from the real world into the virtual world and out again' [33]. While promising, the variety of factors that impact this transition are poorly understood, and we seek to unpack them in this paper.

EXPLORING THE MOMENT OF EXIT

Together, the exploration of presence, simulator sickness, learned skill, and changes of perception covers a broad swathe of the experience of VR. However, there is a moment between the end of the in-VR experience, before the headset is taken off, and the first few seconds of re-entering the real-world, that goes unexplored using these measures. We believe these moments will draw upon factors covered in both the presence literature and simulator sickness in particular, such as concepts of control, involvement, and proprioception. Yet they may also come to include wider considerations that have not previously been brought to light. For example, do VR users become socially anxious about the real-world environment during removal of the headset? Do users attempt to reorient themselves within their mental model of the room, prior to removing the headset? How do users experience a change of ability (i.e., not being able to do something they were previously able to in VR) or the realization of an experiential conceit (e.g., from an illusion)? We explore the moment of exit in order to uncover whether this presents new design opportunities for VR experiences.

Method

In order to explore the moment of exit in VR, we examined both the VR literature and commercial applications of VR to create categories of experience and developed/selected four associated VR applications. Twenty-four participants were invited to use one of these applications and, upon exit, were interviewed about their experience.

We use the explicitation interview technique [28,42] as the launch point for our methodology. This only partially succeeded to provide the nuanced and detailed insight that we were looking for, however, as participants struggled to move beyond descriptions of headset weight and changes in brightness. When necessary, we supplemented a semi-structured interview approach, in which participants were additionally asked about emergent themes from previous interviews and concepts from the presence literature (such as transitions from being 'there', to being 'here' [35]).

Four scenarios to examine the Moment of Exit

To maximize the generalizability of our findings, we explore the moment of exit across four scenarios that span the current primary use cases of VR[1].

Gaming – Complex Environment Switches

A large portion of the commercial effort of VR development is aimed at entertainment and gaming. Gaming uses a large set of mechanics to create immersive VR experiences, including detailed storylines, varied gameplay types, and tension. To this end, games often stray further away from reality, offering magical abilities and infeasible spatial environments. Given their fantastical environments, transitioning from a game back to reality will likely involve the greatest environmental transition.

To explore the moment of exit in gaming, we selected a popular VR mini-game, *The Cubicle*[2]. In this game, users

[1] This is not intended as a complete taxonomy of VR, rather simply to motivate our choices of VR experience.

[2] The Cubicle, Jespertheend, 2016. (Available on Steam)

stand within an office cubicle and stack paper files into a filing cabinet (Figure 1, top left). As this task progresses, the cubicle itself changes and is transported through a variety of large-scale, fantastical environments. The game involves both basic player movements (picking up and placing files), but also supports spatial and object exploration and interaction. At the end of the game, the screen fades to black and the credits begin. Prior to the experience, participants were instructed to remove the headset when this happened.

Illusions – Immediate body re-orientations

Recently there has been increased attention on VR illusions (see Gonzalez-Franco and Lanier [17] for a review). Within HCI, this has focused on haptic illusions [3,8] and walking illusions [21,47], with the intention of enhancing the haptic or spatial richness of the virtual environment. We believe the moment of exit in these illusions is especially interesting, as it corresponds to the moment that users realize they faced an illusion, and must quickly re-orient themselves within the real environment. There can be many different experiences bound to the realization of this deception. For example, participants may exhibit surprise [8], or mild-discomfort [21]. The way in which these experiences arise remains unclear, however.

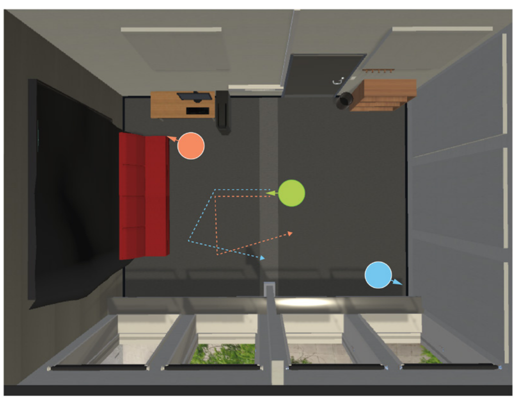

Figure 2. Illustration of the Illusion Scenario. The player starts in the green location in both the virtual and real environments. By slightly varying the player's rotation in VR, the player ends up in one corner of the room in VR (orange), but in the opposite corner, facing the opposite direction in reality (blue).

We built an accurate 3D model of the physical room in which the study would take place. The participants entered VR and were correctly spatially located within the room. The participants completed a task that required them to locate and select a series of boxes around the room (Figure 1, top right). During the task, we applied redirected walking techniques (namely, dynamic rotation gains [47][3]), such that the participants' location in the real and virtual worlds could be de-synchronized. By the end of the experience, the participants were in a different location in the virtual room than in the real room – they had been rotated through 180° and were stood in the opposite corner from where they expected (see Figure 2). The participants see a 'DONE' sign on the wall in front them, at which point they removed the headset (based on prior instruction).

Perception – re-orienting social belief structures

A body of work also explores giving novel experiences in VR to change our social belief structures [20,27]. For example, literature explores changes in perception arising from making people old or young [4], black or white [24], or short or tall [45].

In this scenario, we draw upon the literature on different body characteristics [13,45] – in this case, the Proteus effect – in which users of different heights exhibit different responses to stimuli. This could also be described as a body-schema illusion. Our focus here is on exploring the environment and completing a task from a different height perspective (a maximum of 15% taller and shorter during the scenario). The moment of exit here involves both a body re-orientation (adapting to a sudden change in height), and also a perspective re-orientation and reflection.

The player enters VR and is located in a virtual copy of the physical room. The virtual room is split in half, however, with a semi-transparent wall that acts as a see-through display (Figure 1, bottom right). On the other side of the wall stands a computer controlled agent. The user then engages in the Ultimatum Game [5][4], playing the role of the responder. During every iteration of the game, the responder is either taller, shorter, or the same height as in reality. The user is free to explore the space as they wish, but are encouraged to play the game. At the end of the experience, a message on the virtual wall said 'DONE', and the participants could then remove the headset.

Cognitive – Lifting cognitive burden

As previously discussed, virtual environments have been popular as an educational tool and literature has explored the learning effect of VR (e.g., [19,23,43]). The emphasis on learning and knowledge retention places cognitive burden on the user. The moment of exit, as this burden is

[3] In this technique, rotations in a certain direction, left or right, are sped up or slowed down. If the rate of change is kept low, the participants are unaware of the illusion. In order to verify this, we ran a series of pilot tests. Even when made aware of the illusion, our pilot participants were unable to determine when the rotation gains were occurring.

[4] The agent, the nominator, gets given an amount of money Y from the range [0, A]. The range and the probability distribution of the amounts are known to the user. The agent then decides how much to tell the user they were given in total, and what proportion they want to give to the user. So, the agent may have been given $100, but may tell the user they were given $50, and want to give the user $20. The user then decides whether to trust the offer (in which case the user gets the offer money, and the agent takes everything else), or reject the offer – in which case both 'players' get nothing.

lifted, may result in a different user experience of exiting the virtual environment, perhaps characterized by relief or reflection on task performance.

The participants took part in a cognitively straining n-back memory task [16]. In this task, participants stood in the middle of a room, while a grid of 4x4 boxes floated in front of them (Figure 1, bottom left). Randomly, one at a time, the boxes would flash. If the same box had previously flashed three boxes ago (we used 3-back for our task), then the user had to hit a button on their controller. In this instance, the room was a basic VR space (a continuous grey floor, with an off-white horizon). The space was kept plain to focus the experience on the cognitive strain, and not the world/spatial re-orientation upon exiting. At the end of the experience, the participants could see 'DONE' hovering where the boxes had been, and could then remove the headset.

Procedure

We invited 24 participants (ages 20-43, M=29, 13 female) to participate in our VR scenarios and used a semi-structured interview to explore the experience of exiting VR. The participants were recruited using local mailing lists and had little to no previous experience with VR.

The participants were randomly assigned to one of the four scenarios. Prior to the study, participants were told that we were interested in gauging their experience of VR. The participants were in the virtual environment for approximately 10 minutes. Then, a message appeared in front of the participants telling them that the demo was over. (In the case of *The Cubicle* participants were instructed to remove the headset when the end credits appeared). The participants then removed the headphones and the headset.

Upon removing the headset, the participants were informed that we were actually interested in their experience of leaving VR, specifically the transition from virtual reality back to reality. The experimenter then started with a very open-ended question: *'What was it like, taking off the headset?'* From here, the experimenter worked with the participant to unpack the details of the experience of taking off the headset. Finally, the participants were asked to speculate about new concepts that would heighten (make the transition harsher, more abrupt, more startling) or lessen (make the transition more comfortable, easier) the experience of exiting VR. The participants were given no cues to help with this speculation, but were asked to formulate their ideas based on their VR experience in the study.

The interview was audio-recorded and transcribed. On average, the participant responses were 1035 words long (1 page similar to this).

In total, the VR experience and the interview lasted approximately 25 minutes. The participants were compensated the equivalent of $15.

Apparatus

We used an HTC Vive room-scale VR system. This was located in a 5.7m x 4.2m room. This room is slightly larger than the maximum recommended tracking space as defined by HTC, but we had no issues with tracking. The participants held two HTC Vive controllers (except for in the Illusions scenario, where they used only one). The Vive headset was connected to a PC with a cable. The PC was located against a wall in the center of the room, in a position that allowed the participant to explore the full space of the room.

In order to support the Illusions scenario, we disabled the HTC Vive's standard room boundary markers (a semi-transparent grid). In the Illusions scenario, participants were told to walk directly between target boxes, avoiding any risk of wall collisions. In the other scenarios, the scale of required movement (Gaming and Cognitive scenarios) or the direct mapping between the virtual and real room (Perception scenario) prevented collisions.

Analysis

The interviews were analysed using Thematic Analysis [2]. The thematic analysis departed from the emergent themes from the interviews. The first author developed the coding manual and did the coding. This was later revised again based on an orthogonal and independent analysis by the last author. The themes and their corresponding quotations were digitized into a custom tool that enabled easier analysis across participants. This thematic analysis highlighted six recurrent topics of discussion: space, control, time, sociality, sensory considerations, and future opportunities. We return to a discussion of the future opportunities later in the paper.

Space

The participants' spatial experience of exiting VR varied between having maintained a constant sense of their physical surroundings during VR (8 participants): *'I was sure I'd be somewhere in the middle, I didn't really move that much'* (P20, Gaming) and experiencing surprise at the specifics of their real location/orientation (13 participants): *'at first, I was surprised at where I was in the room'* (P6, Illusions) and '*it was just, I lost my sense of presence, or my direction sense'* (P11, Illusions). Participants who did end up in a different or unexpected location described the sensation as 'surprising' and 'weird.' P2 described the spatial displacement in the Illusion scenario as '*unsettling, but also exciting*'.

In the Perception scenario, where players' height changed whilst in VR, participants' disorientation came mainly from perceptions of scale '*The sofa was smaller'* (P22, Perception) and '*I had the feeling that some of the proportions are not so…*' (P17, Perception). Interestingly, however, none of the participants noticed their own height change, but rather noticed the effect of this height change as it was manifest in their surrounding environment: '*I tried to* *touch stuff on the side but they weren't really there*' (P1, Perception).

As could be expected, the surprise in spatial placement was most prominent for those in the Illusory scenario: '*it was really confusing when I got the headset off*' (P11, Illusions) and '*It was a bit disorienting, because I had expected to be facing the other way*' (P2, Illusions). Perhaps surprisingly, however, was the mild disorientation experienced by participants in the Cognitive scenario. The environment was a basic empty space, with an infinite horizon, that did not require any movement. While the task was relatively simple, it did require concentration, and this was sufficient to introduce some disorientation: '*I thought I was just maybe [at a] 0-20 degree angle, but I was like at 45'* (P18, Cognitive) and '*you need to focus a little bit on where you were.*' (P3, Cognitive)

Finally, in the Gaming scenario, the office cubicle was relatively static, allowing the participants to maintain their global sense of orientation. Participant 20 also reported that the cable of the VR headset (connecting it to the PC) provided a static reference point to support their orientation.

Control

Participants described changes in their sense of control as they transitioned between VR and reality. P22 (Perception) described relief upon exiting VR as '*maybe I trust this world a bit more.'* Upon leaving the Illusions scenario, P2 described re-checking the VR (by bringing the HMD back up to their face), making it easier for them to accept their disorientation: '*I was facing the wall instead of the couch, and I looked again to see if… I was just confused or if it was correct that it was two different things'*. From their experience, P2 also suggested some discomfort with being tricked: *'it's not nice to know that I'm so easy to trick… if I had known it before, it would be more fun.'*

Alongside visual discontinuities, some participants felt changes in body ownership upon exiting VR*. 'It was weird to be able to look down and see my body again… that feeling of going from not really having a body, but just floating… to actually having a body, that's the most drastic change*' (P4, Gaming).

A number of participants drew parallels between exiting VR and science fiction movies. For example, one participant related exiting VR to being unplugged from the *Matrix* (where the exiter themselves is not directly in control) (P10, Illusions), and made links between exiting VR and the layers of dreams in *Inception* (P10). A second participant described the sensation akin to that of Jake in the movie *Avatar*, where the overriding emotion of returning to reality is that of disappointment (P19, Cognitive). P5 accurately summarizes the link between all of these references:

> *'I mean, I like to know that I am stepping out of VR, and not confusing the two… it gives me some sense of a lack of control, or I don't know, like the whole confusion of: is this VR now, or is this real life?'* (P5, Perception)

One participant described the experience as 'invasive', as if '*I was in a dream, that I knew I had to wake up'* (P19, Cognitive). This sensation was heightened as she felt as though someone had been manipulating 'her dream.' Though this experience is not only bound to exiting VR, the immersive nature of VR means that it is only upon exit that these emotions come to light.

Conversely to these negative experiences, P7 (Cognitive) described the sense of gaining control as they exited VR: '*[Its] harder to control than what you'd compare to in real life, so you sorta gain control when you come out.'*

On aggregate, our participants did not experience large, direct changes in their sense of control. We believe this is because the VR headset allowed walking around, and the handheld controllers provide an embodied anchor into the experience. Furthermore, in none of our selected experiences, did participants have any 'abilities' that they lost as they left VR; a factor that may influence their sense of control.

Sociality

Participants were made aware of the interview following the VR experience, prior to taking part. As a result of this, participants reported an awareness of the experimenter, and their role in the subsequent interview, upon exiting VR: '*So I took it off, and I had to go, like, 'Oh, there you are''* (P3, Cognitive). Only one participant indicated surprise about the experimenter: '*I thought you were sat by the computer… I didn't know you'd be sitting here. I was a little surprised by that*' (P3).

Otherwise, participants described feeling safe in the experimental setting, *'But I mean, this is kind of a safe environment'* (P23, Illusions), and thus not consciously thinking about the experimenter. One participant, with prior experience of VR, described a previous scenario where he had to '*fall on the ground'* (P2, Illusions) in VR and could hear those around him laughing. Only in that scenario did he feel self-conscious.

Sensory

Taking off the headset resulted in quick changes to sensory stimuli. Participants described having to quickly adapt to changes in lighting and texture: '*I think I had to adapt, because the contrast [in reality] is much higher'* (P22, Perception). Interestingly, in the Learning scenario, participants commented that the bright horizon helped the transition back to the bright room '*it was nice… when I took the headset off the light was sort of similar to the kind of light that was... in the background here'* (P3, Cognitive).

Time

Participants were also asked to describe the precise moment at which they transitioned from virtual reality to reality.

Across all experiences, a number of participants suggested that the virtual reality stopped being their active reality even before removing the headset: '*I think it was even before I took the headset off*' (P22, Perception) and '*When I saw the done sign, I was even more like, okay I am in a room with a headset on, doing weird stuff*' (P23, Illusions). One participant described a difference between mentally being back in reality and physically being back (P21, Gaming). This suggests that the participant was already thinking about the real room before commencing taking off the headset, but was only physically present with the introduction of the visual and auditory senses. P4 (Gaming) stated '*I wasn't back in room state still… I got the feeling of getting my body back only when I took off the glasses.*' Finally, one participant describes a transitionary gap between exiting VR (when the game is over) and re-entering reality (when removing the headset). When asked to describe what the inter-period gap is like, they said: '*It's a bit like the break between words. It's not something I think about.*' (P16, Gaming).

Discussion

We ran a study to explore the user experience of the moment of exit in VR – the transition from the virtual environment back to the physical environment. To this end, we selected/developed VR scenarios to cover the broad range of existing VR use cases and elicit different responses to the moment of exit. Our expectation was that the Illusion and Gaming scenarios would elicit the strongest response from participants upon exiting VR. While participants described the greatest sense of surprise and disorientation upon exiting the illusory scenario, similar themes of experience were described across all of our participants.

Regardless of the complexity of the scene, participants described differing magnitudes of spatial disorientation. For example, even in a stationary task (the Cognitive scenario), the cognitive load of the task led to some orientation-related confusion. Across our Illusions and Perception scenarios, it became interesting to note the speed with which participants accepted and trusted a virtual environment that was similar to their physical environment. As a direct result of this, subtle changes here (to either the real or virtual environments) may present a range of opportunities for novel exit experiences.

Participants described their spatial disorientation as 'surprising', 'unsettling', 'exciting', and 'weird'. These descriptions could all encourage new game mechanics in VR in which the player actually removes the headset. For example, 'unsettling' spatial disorientation could be used in the moment of exit to heighten tension. Pursuing disorientation as an experience designer would be directly at odds to the previously negative connotations of spatial disorientation as a feature of simulator sickness [15]. However, given the recent advances in VR hardware, and its effect on reducing simulator sickness, certain types of disorientation (such as represented by 'surprise') may yet come to represent positive experiential opportunities.

Participants also described different notions of control in exiting VR. Although the descriptions here were varied, the experience was largely bound to the security that comes from knowing the headset can be removed, to immediately return to the real environment. While novel 'exit' explorations may come to violate this security (such as with drastic changes to the surrounding environment), it is important to note the potential emotional scale of any intervention.

There were also details of exact exit timings that varied across participants. Where some felt the virtual reality stopped being their present reality as soon as they were aware they should remove the headset, others described not returning to actual reality before visual and auditory senses were again available. Further, others describe a clear separation of mental and physical presence upon exit, with a mental exit happening initially, while the headset was still on, followed by a physical exit, when removing the headset. Biocca [6] describes three unique forms of presence: the physical environment, the virtual environment, and the imaginal environment (such as in daydreaming). The descriptions provided by our participants suggest the existence of a temporal structure to the transitions between these environments (i.e., the transition is not instantaneous). This transition period may present potential for intervention, such as lengthening the transition period between the virtual and real environments to heighten tension. This could be achieved by making users mentally aware of specific features of their physical environment (such as the sound) for a period of time before they remove their headset (and complete their transition back to the physical environment).

Finally, participants also described both social and sensory experiences in exiting VR. The social experiences revolved around being observed, with the sensory around visual adaptation back to the real environment.

To explore the opportunities within these experiences of exit, the participants were asked to speculate about interaction opportunities to both heighten and lessen the experience of transitioning from VR to reality and how they may be experienced. We present these concepts next, alongside the related experiential details provided by the participants.

RESULTS - HEIGHTENING AND LESSENING THE EXPERIENCE OF EXITING VR

The participants speculated about new VR concepts for heightening or lessening the experience of leaving VR. Four of these concepts focused on changes within VR, prior to removing the headset, and two focused on changes to the real environment. Figures 3 – 8 were sketched based on the participants' responses.

Abrupt vs Open Endings

VR scenarios can force the user's exit by closing the application, or leave the VR world accessible to the player during the exit moment.

Figure 3. Illustrating Abrupt vs Open Endings. Left: an abrupt ending (fade to black), forces the player to exit VR. Right: the game world remains visible while suggesting an exit, leaving the player in control.

Across our four VR experiences, different exit strategies were used, including fading the view to black (thus providing no sensory stimulus during exit) and leaving the game-world visible with an overlaid 'Done' sign. Some participants felt a lack of control in being forced from VR ('*[if the view remained] I would ask if I could keep playing'* P21, Gaming) where other participants expressed their disappointment at returning to reality ('*getting back to reality, it's just a little disappointing actually.*' P15, Gaming) and stated that, given the opportunity, they would rather choose to continue. One participant, P7, suggested that transitioning back to reality from an 'off or dark' screen would be less visually comfortable.

A soft transition: See through HMD at the End

As a VR experience ends, the view of VR could slowly fade out, as reality begins to slowly fade in. The then see-through HMD allows the user to orient themselves in the room, adjust to lighting and the social setting, before removing the headset. This lessens any abrupt changes in environment upon exit.

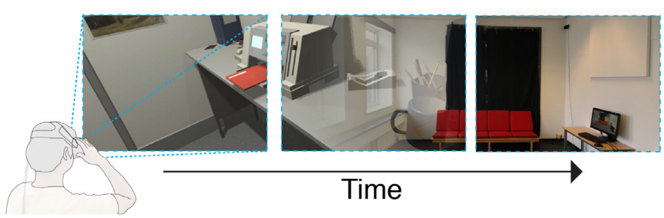

Figure 4. Illustrating Soft Transitions. From left to right, the game world softly fades into the real world, allowing the player to re-orient themselves before removing the headset.

This concept was discussed by four participants. Two participants stated that they would like this experience, easing the transition back into the physical space of reality. Although not explicitly stated, this may help to unify the mental and physical transitions between VR and reality, counteracting some of the inconvenience of physical removing the headset. One participant described this concept as a potential loss of freedom, however, preferring to choose their own moment of exit rather than having the transition forced upon them.

Scale Alignments

As the VR scenario draws to a close, the application could dynamically reposition items of interest, or the environment itself, to the same physical scale as the player's room, helping the player to subtly adapt to the scale of the real environment around them.

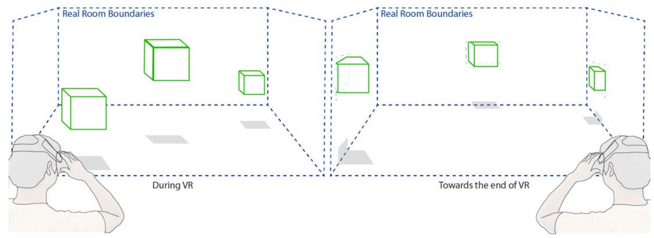

Figure 5. Spatial Alignment illustration. Towards the end of the game, objects of focus are moved to the extremities of the real-space, helping the player adapt to the real-world proportions before exiting VR.

One participant described the relative spatial simplicity of transitioning back to the real room from VR, due to a common scale of attention: '*I didn't notice that much because my eyes were looking at cubes, which felt sort of the same distance to the wall*' (P3, Cognitive). By drawing the VR environment into the same scale as the player's physical surrounds, such as making a final room the same size as in reality, or bringing objects of focus to the boundaries of the physical space, the player may subtly adapt to the scale of the space they are about to enter.

Ability Dashboards

Ability Dashboards in VR can make users aware of their changing abilities. For example, if, in VR, the player can summon objects from distance, a dashboard can show this ability. As the participant begins to exit VR, the dashboard can show that this ability has been disabled.

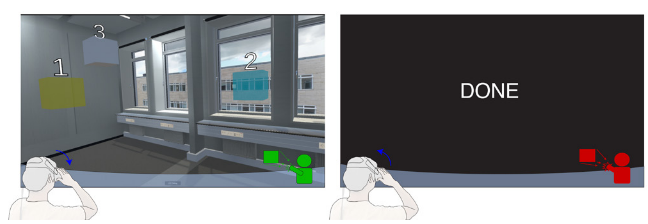

Figure 6. Illustration of Ability Dashboards. A heads-up-display shows the participant special capabilities that are enabled in VR (left) and shows them disabled before removing the headset (right).

One participant, P4, described the transition between things they could do in VR and could not do when they returned to the real world. As an example, if driving in VR, driving ability and its outcomes may be very different from those in reality. A dashboard of capabilities may both help the player orient themselves in VR, and prevent sharp changes in sense of control upon exit.

Room Reconfigurations

Reconfiguring the physical layout or properties of the real room, whilst the player is in VR, to elicit a greater response upon exiting.

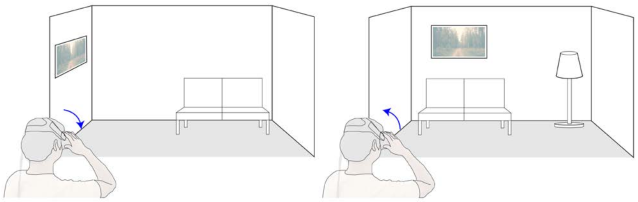

Figure 7. Spatial Reconfiguration illustration. Left: the room layout as the player enters VR. Right: The re-arranged layout (where furnishings have moved) as the player exits VR.

Most participants suggested that any change to their surroundings, if achieved without their knowledge would be an uncomfortable experience. They describe a safety in knowing that their current experience is bound to the physical headset and that, at any time, they can quickly remove the headset to 'escape.' They suggest there may be times at which room scale reconfigurations could aid the experience, for example in horror games with friends, but that, in general this would be an uncomfortable experience.

Similar concepts were explored in VR in TurkDeck [9], where walls were dynamically constructed to further the player's experience in the VR world. Our participants propose leaving the VR world unadjusted, choosing instead to vary the physical-world that the players return to.

Social Setting Changes

Additional people silently enter the room whilst the player is in VR, creating a heightened social awareness upon exiting VR.

Figure 8. Illustration of Social Setting Changes. Left: the social setting of the space as the player enters VR. Right: The social setting upon exiting VR, where multiple people are present.

This experience is similar to the previous Room Reconfigurations, changing the social landscape rather than the physical landscape of the room. The participants described the sudden realization that there were multiple people in the room as they exit VR as a more uncomfortable experience than the previous room reconfigurations. While some of the participants had previously partaken in activities where they were surrounded by non-VR participants, this was typically undertaken without complete sensory isolation (i.e., without noise cancelling headphones). This, in turn, allowed for collaboration or discussion whilst in VR, making the social experience more integrated into the visual VR experience itself, as in ShareVR [18]. Without knowledge of those around you, and outside of the informed VR study setting, the experience of being watched in VR was met with discomfort by our participants ('*that would have been creepy*' (P5)). They described both social isolation (as indicated by the headset) and trust issues with wearing VR in an unknown and 'unsafe' environment.

DISCUSSION

We explored the moment of exit in VR. Where presence measures the extent of 'being there' in the virtual environment (e.g., [34]), the moment of exit details the transitionary experience from 'being there' in VR to 'being there' in the physical reality. Our exploration revealed five recurrent themes of experience: space, time, control, sociality, and sensory considerations. If we consider non-illusory experiences first, it appears that the scale of the exit experience (e.g., the disorientation and confusion, in the Spatial theme) depends on a combination of (a) how present the player is in VR, (b) the movement required within VR, and (c) the time spent in VR (participants commented that their experiences were bound by their length of participation in VR).

Even when in a simplistic environment for a short amount of time (in the Learning scenario), some participants reported disorientation upon exit. We suggest that the cognitive burden of the task led to greater presence and, thus, less focus on the cumulative effect of their movement. In turn, this suggests that some aspects of presence, such as cognitive load, may in fact lead to effects currently considered to be simulator sickness [22], such as disorientation. Though visually immersive, the Game scenario bound the player's movement within a small cubicle and led to little disorientation upon exit: '*I was sure [I] was gonna be somewhere in the middle, because I didn't move that much*' (P20).

Illusory experiences offer an opportunity to push beyond the trade-offs of presence, movement, and time spent in VR, when exploring the spatial experience of exit moments. In our Illusions scenario, we used redirected walking to heighten the players' spatial confusion upon exiting VR. However, participants reported relatively tame experiences: '*I was a bit startled*' (P6), '*that was kind of weird*' (P11), and '*it was a bit disorienting*' (P2). We remain optimistic that further exploration of illusions can deliver the 'Holy S***' of Azmandian et al. [3].

The space and control themes seem closely related, with a lot of control comments relating to trust of the digital environment resulting from spatial disorientation. However, control also alludes to participants' capabilities within the VR world. Participants reflected on visually 'getting their body back' upon exiting VR and the effect this has on their locomotion: going from '*floating… to actually having a* *body*' (P4). Most important for control, however, was the security the participants reported from knowing that, at any time, they could remove the headset to return to reality.

The participants described a number of experiences that could lessen or heighten the experience of exiting VR. We find it interesting that the participants' suggestions for easing the transition back to the real world (lessening the exit experience) focused on 'within VR adaptations', whereas their suggestions for heightening the transition experience focused on real-world changes, such as social or spatial reconfigurations. Social reconfigurations could lead to self-consciousness or awkwardness, for example, leading to a heightened experience of exiting. If we explore changing VR experiences, such that the experience crosses the boundaries between VR and the real-world, then we come to violate the previously mentioned sense of security that comes from being able to remove the headset. This raises important ethical considerations about how we, as designers, describe the scope of these experiences.

Slater et al. [32] explored momentary breakdowns of experience while in VR. Originally, these partial moments of exit, where the user exited mentally but not physically (they became consciously aware of their environment, without physically removing the headset on), were explored as a negative aspect of the VR experience. The depth of experiences reported in our work, however, suggest an opportunity in incorporating temporary exits into VR experiences, thereby merging the virtual and physical worlds. What's more, if we incorporate alterations into the real world as well, such as spatial or social alterations, then both the virtual and the real environments become 'experiences' within one greater whole.

At CHI 2017, ShareVR explored the collaborative role of a non-HMD user within VR [18]. However, the richness of the moment of exit suggests a wealth of opportunities in extending the ShareVR concept to also use the non-HMD user to build exit experiences. For example, alongside assisting in VR, the non-HMD user could engage in room alterations (such as moving furniture, changing lighting, etc.) to increase the HMD-user's disorientation upon exit. In this way, ShareVR [18] could include transition experiences as the players swap headsets.

Though the exit experience of VR appears distinct from presence (as it also draws upon aspects of immersion, features of game design, and length of play, for example), it is interesting to note that presence continues to play a role. Indeed, future exit moment questionnaires could come to include concepts from presence questionnaires, such as control and predictability, alongside questions regarding (a) the sense of being fooled or tricked, (b) embarrassment, (c) social anxiety, (d) comparison (i.e., between worlds), and (e) matching (how well our environments, bodies, or capabilities 'match' between worlds). Further, as VR technologies have developed to reduce and almost mitigate simulator sickness, we now begin to explore using features of simulator sickness (such as disorientation and proprioceptive effects [3]) as an aspect of design. In this way, aspects of simulator sickness should also be added to future exit moment questionnaires. We believe, from the experiences and opportunities gathered here, that this remains an interesting avenue for future work.

Exiting VR may also present similarities with entering VR. While we suspect some aspects of the experience are stronger in transitioning from the virtual to the real (exiting VR), for example spatial differences, it may be that all of the different themes reported here occur when transitioning in either direction (entering or exiting VR). This also remains an avenue for further exploration.

There are limitations in our work. First, our VR scenarios were short (~10 minutes) and this could have a direct impact on the scale of the exit moment. While it is promising that, even over a short period, the participants could provide rich experiential descriptions, longer periods in VR prior to exit may reveal as yet undiscovered aspects of the experience. Second, our study looked at the experience of one exit moment, and thus further research is needed to explore how the experience may change or develop across repeated exits. Finally, though we explored scenarios that cover the broad usage of VR, there is nuance within each of these categories of usage that we have left unexplored. Examples include, magical abilities in VR games, proprioceptive illusions, and skin color changes. These different experiences may provide further depth to our understanding of the moment of exit in VR.

CONCLUSION

We explored the moment of exit in VR. Other aspects of the experience of VR are well understood, from presence to the aftereffects of VR. However, the momentary experience of exiting VR is not well understood and may yet represent a new experiential space that can be designed for.

We explored the moment of exit across four different VR experiences. Twenty-four participants described aspects of spatial awareness, control, sociality, sensory adaptations and details of the precise temporal moment of exit. Participants also described changes to VR (both within the virtual and the real environments) that may both heighten and lessen the experience of exiting VR and speculated as to the experience of these.

With a better understanding of the moment of exit in VR, it may become possible for the experience of VR to be extended beyond the view within the headset. Some research is exploring this already, with haptic extensions [3] for example. However, with a clearer understanding we can design transitions that heighten scary experiences, facilitate spatial security through gradual exits, or better control the users' lasting impression of the experience.

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