Addressing Bystander Exclusion in Shared Spaces During Immersive Virtual Experiences

André Zenner, Donald Degraen, Antonio Krüger
German Research Center for Artificial Intelligence (DFKI)
Saarland Informatics Campus
Saarbrücken, Germany
{firstname}.{lastname}@dfki.de

ABSTRACT

In today's consumer virtual reality (VR) systems, head-mounted displays (HMDs) remain the dominant interface for experiencing immersive virtual environments (VEs). As the focus generally is on maximizing the sense of presence, the immersed user stands isolated while collocated bystanders are excluded from the virtual experience. This disconnect between the physical and virtual world negatively influences social acceptability of immersive VR applications. In this position paper, we discuss two approaches to address the usage of HMDs in shared spaces, specifically tackling the problem of excluded bystanders. First, we promote the idea of immersive notifications that allow non-immersed users and real-world systems to communicate real-world information to an immersed user while maintaining experienced presence. In a second example, we describe a projection-based system for bystanders to experience substitutional realities in a semi-immersive manner, additionally providing a means to interact with the VE without requiring HMDs.

KEYWORDS

Social Acceptability of VR; Immersive Notifications; Substitutional Reality; Involving Bystanders.

CHI'19 Extended Abstracts, May 4-9, 2019, Glasgow, Scotland UK
Proceedings of the 1st Workshop on Challenges Using Head-Mounted Displays in Shared and Social Spaces.

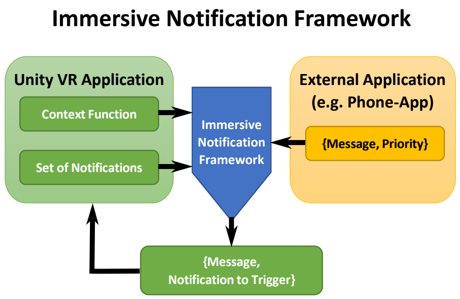

Figure 1: Architecture of the immersive notification framework (from [15]).

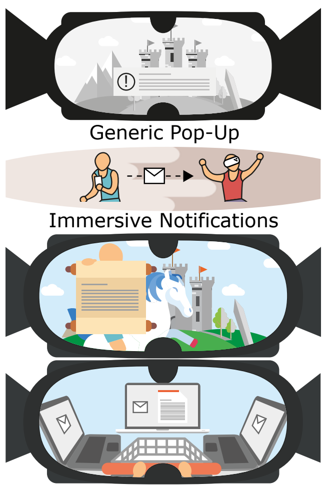

Figure 2: Immersive notifications (from [15]): Instead of a generic pop-up, a mounted messenger approaches the user in a medieval VE with a letter containing a received message. When shopping in a VR electronics store, however, the message might be displayed on exhibited screens.

INTRODUCTION

State-of-the-art virtual reality (VR) systems have grown to optimize the user's experience through an interplay of mixed sensory stimulation. While the focus on maximizing the feeling of presence [11] greatly improves the experience of the immersed user, there exists a clear disassociation with the physical world. In order to reconnect both realities without breaking the virtual experience, we focus on involving non-immersed bystanders by providing them with the tools for communicating with the immersed user and by actively including them in the VE.

Traditionally, interaction with an immersed user relies on a combination of verbal, e.g. talking to the user, or tactile cues, e.g. nudging the user. However, these interactions risk breaking the feeling of presence. When real-world systems, e.g. a user's smartphone, or non-immersed parties, e.g. people in the same room, intend to connect with a VR user, real-world information has to be transferred to a conceptually different world, i.e. the VE. To this aim, we presented a framework that can support designers and developers of VR applications in providing adaptive information presentation, called the immersive notification framework [15].

However, in many application scenarios connecting the physical and the virtual world extends further than event notifications. There is a need towards building an understanding of the actions or movements performed by the immersed user and the experienced VR context in general. Depending on the context, in a shared space bystanders may want to act as passive spectators of virtual events or might aim to actively interact with the VE. Exploring this, we proposed a projection-based bystander interface [13] suitable for substitutional reality [10] experiences while involving passive haptic feedback [3].

IMMERSIVE NOTIFICATIONS

Today's VR systems allow users to pair their devices, e.g. the smartphone, in order to forward incoming notifications while being immersed in VR. Notifications are typically displayed by virtual notification overlays, i.e. generic pop-ups with the notification text, in the user's field of view. This approach is not optimal with regard to the user's sense of presence as the sudden appearance of a generic text pop-up can in many contexts be unexpected, unrealistic and inappropriate. As a result, the plausibility of the VE – and thus a crucial component of presence [11] – might suffer. Motivated by state-of-the-art approaches that do not adapt to the experienced VE, we propose to preserve plausibility when providing the user with real-world information to maintain the feeling of presence [15].

Our concept notifies immersed users with plausible animations and interactions in the VE. These notifications are adapted to (1) the general setting of the virtual world (i.e. aesthetics, story, environment), (2) the current context of the immersed user (i.e. how engaging the user's virtual situation is), and (3) the importance of the message [15]. Developers register application-adapted animations

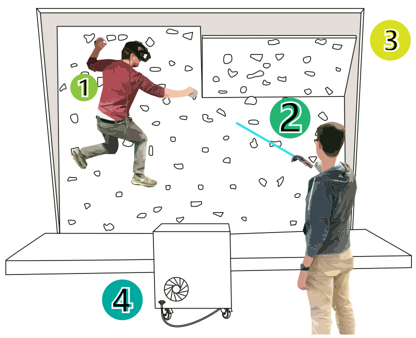

Figure 3: Our bystander interface (from [13]): The VR user (1) climbs in SR wearing an HMD. An active spectator (2) observes the climber and suggests a hold by pointing into the VE with an HTC Vive controller. Meanwhile, the physical wall (3) is transformed into a spatial augmented reality experience as a projector unit (4) projects the SR onto the physical environment.

Figure 4: A bystander's semi-immersive view on the SR climbing experience in a collect-the-presents game (from [13]).

and functions describing the virtual context of the user with a central framework component, which receives incoming messages tagged with a priority (Figure 1). The framework then decides, based on the context of the user and the message's priority, which animation is best suited to present the notification. For example, in an application with a medieval setting the virtual avatar of a mounted messenger approaches the user to hand over a letter containing the text (Figure 2). In a sci-fi game, the mounted messenger might be replaced by a futuristic communication drone. Our open-source implementation[1] is available for use in the Unity engine to showcase an adaptive messaging system. It can serve as a basis for developers to integrate immersive notifications into their VR applications.

INVOLVING BYSTANDERS OF SUBSTITUTIONAL REALITY EXPERIENCES

Beyond notifications, as a second approach we implemented a projection-based interface to involve bystanders in immersive experiences [13]. For this, we investigated how projections can make substitutional reality (SR) [10] experiences with passive haptic proxies [3] accessible to bystanders.

Our proposed solution builds on previous research on projections for everyday environments [4, 5] and in sports [12]. We first identified two types of bystanders and their respective requirements for a bystander interface. Passive spectators aim to perceive the SR while maintaining an overview of both the real and virtual environment. Additionally, active spectators intend to interact with the VE while observing the experience of an immersed user. To meet these requirements, we proposed a system that (1) provides auditory feedback and (2) projects the virtual substitutions onto their physical counterparts in the real environment. This enabled bystanders to perceive the substitutional environment and its spatial relationships in a semi-immersive fashion. Our system allowed active spectators to interact with the VE using tracked input controllers like the HTC Vive controllers. By pointing with the controllers onto the projection and "into the VE" (Figure 5 and 6), users triggered virtual events or provided hints to an immersed user. Our interface was showcased using a system for climbers [6, 13] (Figure 3 and 4).

DISCUSSION

The proposed approaches enhance the social acceptability of VR in shared spaces and tackle the exclusion of collocated non-VR bystanders. Both ideas approach the issue from different directions.

While immersive notifications allow non-immersed users to get in contact with VR users without interrupting their experience excessively, it is a low-level approach targeted primarily at information transfer from the real to the virtual world. Our concept can easily be extended towards a more general and unified framework that takes adaptive notifications into account from the inception phase. This will lower the threshold for developers to ensure more immersive experiences while generating more social awareness and acceptability.

[1] https://github.com/AndreZenner/notifications-framework

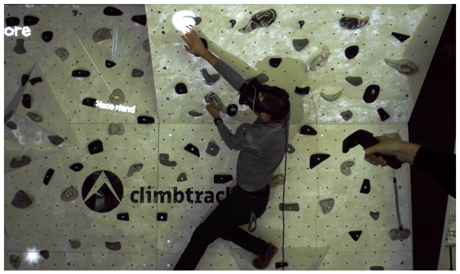

Figure 5: A bystander guides an immersed climber using the controller as a virtual flashlight inside the VE. The virtual night climb environment is perceived through the projection on the real wall. By pointing "into the VE", the bystander lights up a hold on the virtual rock to help the climber (from [13]).

Figure 6: View of the immersed climber wearing an HMD. The climber sees the virtual flashlight of the bystander in the VE. The light highlights a hold on the virtual rock, guiding the climber through the simulated SR night climb (from [13]).

Our second concept provides insights into how asymmetrical experiences of non-VR and VR user interactions might look like in the future. Here, projection-based solutions are well suited for passive haptic environments as props provide projection surfaces turning bystanders into semi-immersed observers. By using tracked devices to interact with the spatially registered real environment, projections can provide visual feedback to active bystanders of SR experiences.

To discuss the issue of bystander exclusion in VR, we believe that both presented concepts fit well into the agenda of the CHI 2019 workshop on 'Challenges Using Head-Mounted Displays in Shared and Social Spaces'. By presenting our approaches, we wish to engage in an active debate to examine the future research potential of asymmetrical and shared VR experiences.

BIOGRAPHY

If accepted, both André Zenner and Donald Degraen will attend the CHI 2019 workshop on 'Challenges Using Head-Mounted Displays in Shared and Social Spaces'.

André Zenner received his Bachelor's and Master's degree in Computer Science from Saarland University. From 2013 to 2016, he worked at the German Research Center for Artificial Intelligence (DFKI) as a student research assistant. Since March 2016, he is a researcher at the DFKI and a Ph.D. student at the Saarland Informatics Campus under supervision of Prof. Dr. Antonio Krüger. His research focuses on the concept of dynamic passive haptic feedback [14] and other techniques that enhance the user's experience when exploring immersive virtual environments. At CHI 2019, he will present a novel haptic controller for virtual reality. Besides research on haptic feedback, he also worked on topics that focused on using VR in shared spaces. In this context, he presented a projection interface to involve bystanders in a substitutional reality climbing experience [13] and the immersive notification framework [15].

Donald Degraen started his Ph.D. studies in September 2016 at the Saarland Informatics Campus under supervision of Prof. Dr. Antonio Krüger and is part of the DISTRO Innovative Training Network. His research leverages fabrication to enhance haptic perception in VR/AR. At CHI 2019, he will present the results of a first study that investigated the use of 3D-printed hair-like structures for enhancing the perception of textures and materials [2]. With a Master's in Computer Science and a specialization in Human-Computer Interaction (HCI), he was involved in research on interaction in the social IoT [1], intelligible interaction [8], alternative route generation [9] and visual peripheral perception [7].

ACKNOWLEDGMENTS

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Marie Skłodowska-Curie grant agreement No 642841 (DISTRO). This research was funded in part by the German Federal Ministry of Education and Research (BMBF) under grant number 01IS17043 (project ViRUX).

REFERENCES

[1] Donald Degraen. 2019. *Exploring Interaction Design for the Social Internet of Things.* Springer International Publishing, Cham, 85–106. https://doi.org/10.1007/978-3-319-94659-7_5

[2] Donald Degraen, André Zenner, and Antonio Krüger. 2019. Enhancing Texture Perception in Virtual Reality Using 3D-Printed Hair Structures. In *Proc. CHI*. ACM, New York, NY, USA. https://doi.org/10.1145/3290605.3300479

[3] Brent Edward Insko. 2001. *Passive Haptics Significantly Enhances Virtual Environments*. Ph.D. Dissertation. University of North Carolina at Chapel Hill, USA. http://www.cs.unc.edu/techreports/01-017.pdf

[4] Brett Jones, Rajinder Sodhi, Michael Murdock, Ravish Mehra, Hrvoje Benko, Andrew Wilson, Eyal Ofek, Blair MacIntyre, Nikunj Raghuvanshi, and Lior Shapira. 2014. RoomAlive: Magical Experiences Enabled by Scalable, Adaptive Projector-camera Units. In *Proc. UIST*. ACM, New York, NY, USA, 637–644. https://doi.org/10.1145/2642918.2647383

[5] Brett R. Jones, Hrvoje Benko, Eyal Ofek, and Andrew D. Wilson. 2013. IllumiRoom: Peripheral Projected Illusions for Interactive Experiences. In *Proc. CHI*. ACM, New York, NY, USA, 869–878. https://doi.org/10.1145/2470654.2466112

[6] Felix Kosmalla, André Zenner, Marco Speicher, Florian Daiber, Nico Herbig, and Antonio Krüger. 2017. Exploring Rock Climbing in Mixed Reality Environments. In *Proc. CHI EA*. ACM, New York, NY, USA, 1787–1793. https://doi.org/10.1145/3027063.3053110

[7] Kris Luyten, Donald Degraen, Gustavo Rovelo Ruiz, Sven Coppers, and Davy Vanacken. 2016. Hidden in Plain Sight: an Exploration of a Visual Language for Near-Eye Out-of-Focus Displays in the Peripheral View. In *Proc. CHI*. ACM, 487–497. https://doi.org/10.1145/2858036.2858339

[8] Gustavo Rovelo, Donald Degraen, Davy Vanacken, Kris Luyten, and Karin Coninx. 2015. Gestu-Wan-An Intelligible Mid-Air Gesture Guidance System for Walk-up-and-Use Displays. In *Human-Computer Interaction*. Springer, 368–386. https://doi.org/10.1007/978-3-319-22668-2_28

[9] Nina Runge, Pavel Samsonov, Donald Degraen, and Johannes Schöning. 2016. No more autobahn!: Scenic route generation using googles street view. In *Proc. IUI*. ACM, 147–151. https://doi.org/10.1145/2856767.2856804

[10] Adalberto L. Simeone, Eduardo Velloso, and Hans Gellersen. 2015. Substitutional Reality: Using the Physical Environment to Design Virtual Reality Experiences. In *Proc. CHI*. ACM, New York, NY, USA, 3307–3316. https://doi.org/10.1145/2702123.2702389

[11] Mel Slater. 2009. Place Illusion and Plausibility Can Lead to Realistic Behaviour in Immersive Virtual Environments. *Philosophical Transactions of the Royal Society of London B: Biological Sciences* 364, 1535 (2009), 3549–3557. https://doi.org/10.1098/rstb.2009.0138

[12] Frederik Wiehr, Felix Kosmalla, Florian Daiber, and Antonio Krüger. 2016. betaCube: Enhancing Training for Climbing by a Self-Calibrating Camera-Projection Unit. In *Proc. CHI EA*. ACM, New York, NY, USA, 1998–2004. https://doi.org/10.1145/2851581.2892393

[13] André Zenner, Felix Kosmalla, Marco Speicher, Florian Daiber, and Antonio Krüger. 2018. A Projection-Based Interface to Involve Semi-Immersed Users in Substitutional Realities. In *2018 IEEE 4th Workshop on Everyday Virtual Reality (WEVR)*. https://wevr.adalsimeone.me/2018/WEVR2018_Zenner.pdf

[14] André Zenner and Antonio Krüger. 2017. Shifty: A Weight-Shifting Dynamic Passive Haptic Proxy to Enhance Object Perception in Virtual Reality. *IEEE Transactions on Visualization and Computer Graphics* 23, 4 (2017), 1285–1294. https://doi.org/10.1109/TVCG.2017.2656978

[15] André Zenner, Marco Speicher, Sören Klingner, Donald Degraen, Florian Daiber, and Antonio Krüger. 2018. Immersive Notification Framework: Adaptive & Plausible Notifications in Virtual Reality. In *Proc. CHI EA*. ACM, New York, NY, USA, Article LBW609, 6 pages. https://doi.org/10.1145/3170427.3188505