It Takes Two To Tango: Conflicts Between Users on the Reality-Virtuality Continuum and Their Bystanders

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ABSTRACT

Over the last years, Augmented and Virtual Reality technology became more immersive. However, when users immerse themselves in these digital realities, they detach from their real-world environments. This detachment creates conflicts that are problematic in public spaces such as planes but also private settings. Consequently, on the one hand, the detaching from the world creates an immerse experience for the user, and on the other hand, this creates a social conflict with bystanders. With this work, we highlight and categorize social conflicts caused by using immersive digital realities. We first present different social settings in which social conflicts arise and then provide an overview of investigated scenarios. Finally, we present research opportunities that help to address social conflicts between immersed users and bystanders.

CCS CONCEPTS

• **Human-centered computing** → *Mixed / augmented reality*; *Virtual reality*.

KEYWORDS

Reality-Virtuality Continuum, Augmented Reality, Virtual Reality, Transitional Interfaces, Bystander

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1 WHAT IS CROSS-REALITY INTERACTION?

We interpret cross-reality interaction as a cause-effect relationship that involves at least two different manifestations of the reality–virtuality continuum [28], whereas a manifestation represents an experience located at a concrete area on the continuum. In other words, an event happening in one reality causes an effect that impacts another form of reality, e.g., augmented reality (AR) or virtual reality (VR). In this paper, we limit ourselves to cross-reality interactions in which users are co-located, and their presence in the same physical space induces specific challenges that need to be considered. For example, a person enters a room where another person enjoys a virtual environment with a VR headset. Then, the entering person starts a conversation (cause), which slightly affects the VR user's immersion and transports the user away from their virtual environment (effect). This example shows an interaction across multiple realities with some adverse side-effects on immersion. In general, the caused effects can be positive and intentional, but in many situations in which these effects are not considered and the challenges that come along remain unaddressed, they can induce negative side-effects, limiting users' experiences. Here, both, user and bystander, need to be considered to guarantee a good user experience. To reflect this, we titled our work *"it takes two to tango."*

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2 INTRODUCTION

In the past few years, there has been great progress in the areas of AR and VR. In particular, technological developments and the availability of head-mounted displays (HMDs) for end-users have made great strides. This enables users both at home and on the go to superimpose digital information in the form of graphic representations over the world or even to immerse themselves completely in virtual realities. Over the past years, technical availability has made it possible for researchers to understand, for the first time, how people can use AR and VR. The main focus here was on how users can better interact with digital information and how information can be better presented to create a better user experience (UX) and better immersion.

The various realities such as AR, augmented virtuality (AV), and VR can be mapped on a continuum – the reality-virtuality continuum [28]. Many applications currently use a specific area on the continuum called a manifestation. For example, training in VR [9, 14, 20], extended environments/workplaces with AR [2, 10, 21], and the collaboration of several people in AV [4, 26, 29]. However, the continuum is a smooth continuance between two extremes, reality and virtuality, that allows endless configurations. mixed reality (MR) expresses everything that is not completely left (reality) or right (virtuality) on the continuum. Improving the UX for users present in different realities has been the great goal of the last few years.

Clearly, the real world never stops surrounding the user and moves at its own pace. People around the user could influence the user's experience in a virtually enhanced or purely virtual environment [26]. Additionally, physical structures from the real world can also influence the user [26] or even incoming digital information in the form of notifications [11, 13, 35, 41]. Understanding these experiences made by the user will become even more important in the coming years and will increasingly crystallize into a new research direction.

Today, the question arises of how the real world can be appropriately integrated into alternative realities to raise the feeling of immersion for the user on the one hand, but on the other hand, not to lose complete contact with the outside world. Today there are first attempts to explore how persons around the user can be directly integrated into the interaction or even enable a conversation between different realities [26]. It is often best to shift manifestation of bystanders and artifacts over time on the reality-virtuality continuum to make an interaction possible [26]. That means either shifting the user towards the real world or bringing the bystanders into an alternate reality. In the simplest case, the VR user would drop their VR HMD and thus would be completely abandon the alternative reality, which would make a conversation possible, but also completely destroys the immersion. Alternatively, the bystander could put on an HMD and dive into the VR, which would also enable interaction, but here comes the problem that the bystander also loses contact with the real world. Consequently, it becomes clear that the two simple solutions are not good solutions and that a good solution lies between the two extremes.

Therefore, the focus should be on the technical realization of alternative realities, as seen up to now, and on the social component of disconnecting the user [38]. This is a main challenge that needs to be addressed in the future. The first signs that isolating oneself from the real world by immersing oneself in an alternative world is causing social challenges that can already be seen in planes and trains [39], for instance, social norms for intractability are not clear [12]. An example is the use of noise-canceling headphones. Although such headphones only overwrite the user's auditory perception, this causes problems, especially at the beginning of conversations [19]. Also, alternative realities are usually fixated on the visual perception of humans. This highlights the problem of social isolation since visual perception is dominant over other senses [33].

In the following, we first discuss different social settings in which the use of alternative realities have been envisioned. In detail, we discuss the different characteristics from which we, in a second step, derive three different relationships between users and bystanders.

3 METHODOLOGY

To derive the different classes of social settings and corresponding characteristics, we crawled relevant literature using *Google Scholar* and focused on two online libraries in particular (*ACM Digital Library* and *IEEE Xplore*), considering work published in the last five years in topic-related conferences (*CHI*, *UIST*, *VRST*, *IEEE VR*, *IEEE ISMAR*). To find relevant papers, we searched for one of the following keywords and their abbreviations in title or abstract: "Mixed Reality," "Augmented Reality," "Virtual Reality," and "Reality-Virtuality Continuum." We collected all relevant papers in a spreadsheet and iteratively added information dimensions classifying the publications. For this paper, we identified different contexts of users and their interaction between them. In the following, we introduce these settings and scenarios in more detail.

4 SOCIAL SETTINGS

Users can experience digital realities in different social settings. While VR often is experienced for entertainment purposes in private settings alone or with friends, the technology becomes more relevant for professional contexts. Furthermore, previous research suggests that public settings can become relevant in the future as well [8]. To understand potential conflicts between users manifesting somewhere on the reality-virtuality continuum and the people around them, we analyzed and categorized related work into three groups: private, semi-private (e.g. school/work), and public. In the following, we present the three different settings of use and their different user expectations and norms.

4.1 Private

Mostly for entertainment purposes, users experience digital realities in private settings. The number of bystanders is relatively low, and users and their activities are known to the bystanders. An example is a group of friends that takes turns on a VR headset. For the additional involvement of bystanders in these gaming activities, different collaborative games exist [7]. Nevertheless, private settings are not limited to indoor but extend to other locations as well. For example, users can experience VR while being in a driving car [16, 27, 30].

4.2 Semi-Private - Work/School

In work or school environments, users and bystanders likely know each other as they are mostly access controlled so that only authorized people can enter and visitors often stand out (e.g. visitor badge). Thus, the users' experience is not necessarily of interest for bystanders and the hurdle to engage in an interaction lower due to the connection they share by being allowed in the space. Moreover, education often requires collaboration between subjects [25, 31].

4.3 Public

In recent years, public settings became more relevant as a social setting for experiencing digital realities. Compared to private or semi-private settings, users and bystanders likely do not know each other. In detail, we can divide the settings in public (e.g. streets, and parks) and semi-public setting (e.g., coffeehouses, and shops). Usage of, for example, VR in public spaces can result in the unperceived presence of others or a less immersive experience due to external interruptions [22, 24]. Nevertheless, using VR in public spaces can have various use cases, such as improving the travel experience during long flights [37, 39].

5 RESEARCH SCENARIOS

In previous work, different scenarios that involve users on the reality-virtuality continuum and their bystanders have been investigated. When studying these scenarios, it becomes visible that often the relationship between users and their bystander differs. Here, relationship refers to the relative position of users and bystanders on the continuum. In the following, we grouped the research scenarios from previous work based on the described relationship between users and bystanders (see Figure 1).

5.1 Isolated Experiences

Isolated experiences exploit the circumstances that users detach from their real-world environments. While this seems to contradict our work's motivation, it still can make sense in certain situations. For example, in a noisy office environment with lots of visual elements causing distraction from work, a virtual environment may

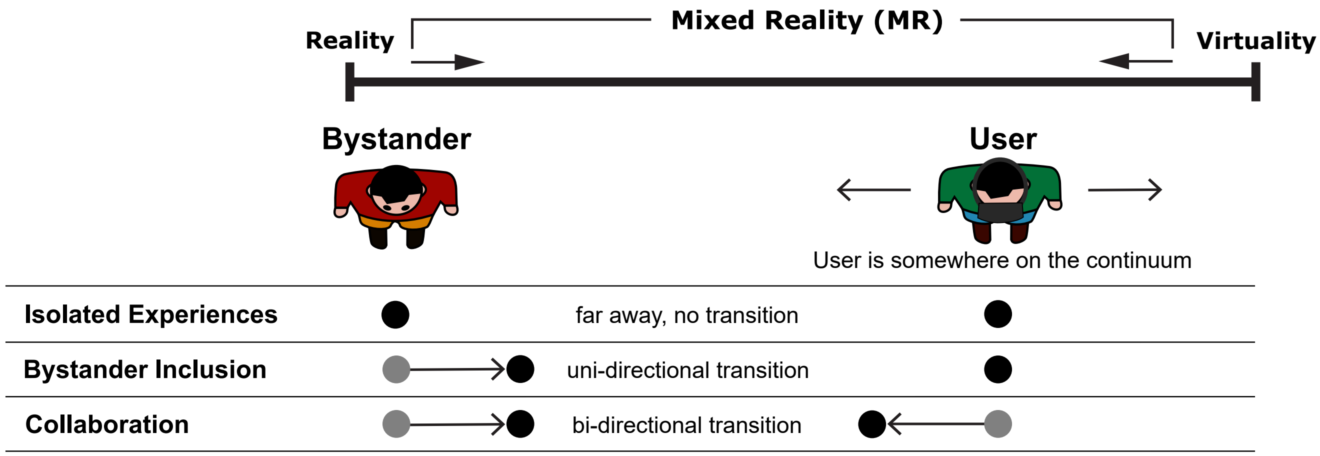

Figure 1: Groups of scenarios that share the same relationship between users on the continuum and their bystanders.

be a good idea to isolate from these negative influences [34]. Another example is a situation in which multiple VR users share the same space but not the same virtual experience [3], or a situation in which bystanders cross the playing area of a user[40]. These examples have in common that both bystanders and users do not have an interest in one another. Hence, the larger the relative distance between them on the continuum, the better is the overall experience.

5.2 Bystander Inclusion

In many situations, users manifesting on certain spots on the reality-virtuality continuum would like to include bystanders in their experience, or bystanders would like to participate in the user's experience. Here, users' experience on the continuum is at focus, and bystanders get included in various ways. For example, bystanders want to see what a user in VR experiences, and therefore, previous work suggests using a CAVE [17, 18] or display attached to the HMD [23, 32]. Another example is to have bystanders enrich the experience by giving different forms of haptic feedback [5, 6]. These examples share that bystanders transition on the continuum towards the user, while the user does not transit. The goal is to keep the user immersed but to empower bystanders to participate in the experience.

5.3 Collaboration

With collaboration, we refer to scenarios that involve achieving a shared goal. Compared to bystander inclusion, this means that both users and bystanders alter their experience and come closer to each other on the continuum, see Figure 1. An example would be a bystander and user playing a game together where the bystander can help the user reach their objective (e.g., to solve a maze puzzle [36]) or where both play against each other (e.g., in a sword fight [15]). In the latter scenario, we stretched the term collaboration a bit; however, we argue that both users still share a goal – having fun together. In sum, we understand this last class of user-bystander relationships as scenarios in which both experiences are altered to perceive each other's presence.

6 RESEARCH OPPORTUNITIES

In the following, we highlight future research opportunities derived from the introduced social settings and classes of relationships between users and their bystanders.

Expanding to Public and Work Places. First-generation VR and AR devices are designed for single-user experiences in private contexts. However, designing devices that foster interaction between users and bystanders can facilitate communication and interplay in various contexts.

Transitional Experiences. New technology might allow easy transitions along the continuum (e.g. video see-through HMDs). Depending on the scenario, it makes sense to create experiences that, for example, allow the user to transit from reality into VR gradually. Thereby users and bystanders can interact on different levels depending on how far they must transit into the reality of each other. Based on the benefits it provides, we expect transitional interfaces to become more relevant in the future.

Visualization Helps Understanding. Researchers and developers might face challenges while investigating or developing MR scenarios and therefore need insights into the sessions of their users. Tools and Frameworks that help us describe or analyze these scenarios [1]. Ways to stronger considerate different social settings (public, work, and private) in research might be key to understand the interplay of involved users, objects, and environments.

7 CONCLUSION

In this paper, we present different scenarios for the use of alternative realities. By categorizing them, we found three different social contexts: private, work, and public in which alternative realities can be used. From these, we derive characteristics of different relationships between the user and bystanders. Here, we argue that three types of interactions are important to explore in the future to enable easy switching between manifestations as this ultimately allows for a satisfying user-bystander interaction.

REFERENCES

[1] Shivam Agarwal, Jonas Auda, Stefan Schneegaß, and Fabian Beck. 2020. A Design and Application Space for Visualizing User Sessions of Virtual and Mixed Reality Environments. In *Vision, Modeling, and Visualization*, Jens Krüger, Matthias Niessner, and Jörg Stückler (Eds.). The Eurographics Association. https://doi.org/10.2312/vmv.20201194

[2] Karan Ahuja, Sujeath Pareddy, Robert Xiao, Mayank Goel, and Chris Harrison. 2019. LightAnchors: Appropriating Point Lights for Spatially-Anchored Augmented Reality Interfaces. In *Proceedings of the 32nd Annual ACM Symposium on User Interface Software and Technology* (New Orleans, LA, USA) *(UIST '19)*. Association for Computing Machinery, New York, NY, USA, 189–196. https://doi.org/10.1145/3332165.3347884

[3] Mahdi Azmandian, Timofey Grechkin, and Evan S. Rosenberg. 2017. An evaluation of strategies for two-user redirected walking in shared physical spaces. In *2017 IEEE Virtual Reality (VR '17)*. 91–98. https://doi.org/10.1109/VR.2017.7892235

[4] Gerd Bruder, Frank Steinicke, Kai Rothaus, and Klaus Hinrichs. 2009. Enhancing Presence in Head-Mounted Display Environments by Visual Body Feedback Using Head-Mounted Cameras. In *2009 International Conference on CyberWorlds*. 43–50. https://doi.org/10.1109/CW.2009.39

[5] Lung-Pan Cheng, Patrick Lühne, Pedro Lopes, Christoph Sterz, and Patrick Baudisch. 2014. Haptic Turk: A Motion Platform Based on People. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Toronto, Ontario, Canada) *(CHI '14)*. Association for Computing Machinery, New York, NY, USA, 3463–3472. https://doi.org/10.1145/2556288.2557101

[6] Lung-Pan Cheng, Thijs Roumen, Hannes Rantzsch, Sven Köhler, Patrick Schmidt, Robert Kovacs, Johannes Jasper, Jonas Kemper, and Patrick Baudisch. 2015. TurkDeck: Physical Virtual Reality Based on People. In *Proceedings of the 28th Annual ACM Symposium on User Interface Software & Technology* (Charlotte, NC, USA) *(UIST '15)*. Association for Computing Machinery, New York, NY, USA, 417–426. https://doi.org/10.1145/2807442.2807463

[7] Arindam Dey, Thammathip Piumsomboon, Youngho Lee, and Mark Billinghurst. 2017. Effects of Sharing Physiological States of Players in a Collaborative Virtual Reality Gameplay. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems* (Denver, Colorado, USA) *(CHI '17)*. Association for Computing Machinery, New York, NY, USA, 4045–4056. https://doi.org/10.1145/3025453.3026028

[8] Pouya Eghbali, Kaisa Väänänen, and Tero Jokela. 2019. Social Acceptability of Virtual Reality in Public Spaces: Experiential Factors and Design Recommendations. In *Proceedings of the 18th International Conference on Mobile and Ubiquitous Multimedia* (Pisa, Italy) *(MUM '19)*. Association for Computing Machinery, New York, NY, USA, Article 28, 11 pages. https://doi.org/10.1145/3365610.3365647

[9] Markus Funk, Mareike Kritzler, and Florian Michahelles. 2017. HoloCollab: A Shared Virtual Platform for Physical Assembly Training Using Spatially-Aware Head-Mounted Displays. In *Proceedings of the Seventh International Conference on the Internet of Things* (Linz, Austria) *(IoT '17)*. Association for Computing Machinery, New York, NY, USA, Article 19, 7 pages. https://doi.org/10.1145/3131542.3131559

[10] Markus Funk, Sven Mayer, and Albrecht Schmidt. 2015. Using In-Situ Projection to Support Cognitively Impaired Workers at the Workplace. In *Proceedings of the 17th International ACM SIGACCESS Conference on Computers & Accessibility* (Lisbon, Portugal) *(ASSETS '15)*. Association for Computing Machinery, New York, NY, USA, 185–192. https://doi.org/10.1145/2700648.2809853

[11] Ceenu George, Manuel Demmler, and Heinrich Hussmann. 2018. Intelligent Interruptions for IVR: Investigating the Interplay between Presence, Workload and Attention. In *Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems* (Montreal QC, Canada) *(CHI EA '18)*. Association for Computing Machinery, New York, NY, USA, 1–6. https://doi.org/10.1145/3170427.3188686

[12] Ceenu George, Philipp Janssen, David Heuss, and Florian Alt. 2019. Should I Interrupt or Not? Understanding Interruptions in Head-Mounted Display Settings. In *Proceedings of the 2019 on Designing Interactive Systems Conference* (San Diego, CA, USA) *(DIS '19)*. Association for Computing Machinery, New York, NY, USA, 497–510. https://doi.org/10.1145/3322276.3322363

[13] Sarthak Ghosh, Lauren Winston, Nishant Panchal, Philippe Kimura-Thollander, Jeff Hotnog, Douglas Cheong, Gabriel Reyes, and Gregory D. Abowd. 2018. NotifiVR: Exploring Interruptions and Notifications in Virtual Reality. *IEEE Transactions on Visualization and Computer Graphics* 24, 4 (2018), 1447–1456. https://doi.org/10.1109/TVCG.2018.2793698

[14] Scott W Greenwald, Wiley Corning, Gavin McDowell, Pattie Maes, and John Belcher. 2019. ElectroVR: An Electrostatic Playground for Collaborative, Simulation-Based Exploratory Learning in Immersive Virtual Reality. In *Proceedings of the 13th International Conference on Computer Supported Collaborative Learning (CSCL '19)*. International Society of the Learning Sciences (ISLS). https://repository.isls.org//handle/1/1761

[15] Jan Gugenheimer, Evgeny Stemasov, Julian Frommel, and Enrico Rukzio. 2017. ShareVR: Enabling Co-Located Experiences for Virtual Reality between HMD and Non-HMD Users. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems* (Denver, Colorado, USA) *(CHI '17)*. Association for Computing Machinery, New York, NY, USA, 4021–4033. https://doi.org/10.1145/3025453.3025683

[16] Philipp Hock, Sebastian Benedikter, Jan Gugenheimer, and Enrico Rukzio. 2017. CarVR: Enabling In-Car Virtual Reality Entertainment. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems* (Denver, Colorado, USA) *(CHI '17)*. Association for Computing Machinery, New York, NY, USA, 4034–4044. https://doi.org/10.1145/3025453.3025665

[17] Akira Ishii, Masaya Tsuruta, Ippei Suzuki, Shuta Nakamae, Tatsuya Minagawa, Junichi Suzuki, and Yoichi Ochiai. 2017. ReverseCAVE: Providing Reverse Perspectives for Sharing VR Experience. In *ACM SIGGRAPH 2017 Posters* (Los Angeles, California) *(SIGGRAPH '17)*. Association for Computing Machinery, New York, NY, USA, Article 28, 2 pages. https://doi.org/10.1145/3102163.3102208

[18] Akira Ishii, Masaya Tsuruta, Ippei Suzuki, Shuta Nakamae, Junichi Suzuki, and Yoichi Ochiai. 2019. Let Your World Open: CAVE-Based Visualization Methods of Public Virtual Reality towards a Shareable VR Experience. In *Proceedings of the 10th Augmented Human International Conference 2019* (Reims, France) *(AH2019)*. Association for Computing Machinery, New York, NY, USA, Article 33, 8 pages. https://doi.org/10.1145/3311823.3311860

[19] Francisco Kiss, Sven Mayer, and Valentin Schwind. 2020. Audio VR: Did Video Kill the Radio Star? *Interactions* 27, 3 (April 2020), 46–51. https://doi.org/10.1145/3386385

[20] Changyang Li, Wei Liang, Chris Quigley, Yibiao Zhao, and Lap-Fai Yu. 2017. Earthquake Safety Training through Virtual Drills. *IEEE Transactions on Visualization and Computer Graphics* 23, 4 (2017), 1275–1284. https://doi.org/10.1109/TVCG.2017.2656958

[21] Hanchuan Li, Eric Whitmire, Alex Mariakakis, Victor Chan, Alanson P Sample, and Shwetak N Patel. 2019. IDCam: Precise Item Identification for AR Enhanced Object Interactions. In *2019 IEEE International Conference on RFID (RFID '19)*. 1–7. https://doi.org/10.1109/RFID.2019.8719279

[22] Christian Mai and Mohamed Khamis. 2018. Public HMDs: Modeling and Understanding User Behavior around Public Head-Mounted Displays. In *Proceedings of the 7th ACM International Symposium on Pervasive Displays* (Munich, Germany) *(PerDis '18)*. Association for Computing Machinery, New York, NY, USA, Article 21, 9 pages. https://doi.org/10.1145/3205873.3205879

[23] Christian Mai, Lukas Rambold, and Mohamed Khamis. 2017. TransparentHMD: Revealing the HMD User's Face to Bystanders. In *Proceedings of the 16th International Conference on Mobile and Ubiquitous Multimedia* (Stuttgart, Germany) *(MUM '17)*. Association for Computing Machinery, New York, NY, USA, 515–520. https://doi.org/10.1145/3152832.3157813

[24] Christian Mai, Tim Wiltzius, Florian Alt, and Heinrich Hußmann. 2018. Feeling Alone in Public: Investigating the Influence of Spatial Layout on Users' VR Experience. In *Proceedings of the 10th Nordic Conference on Human-Computer Interaction* (Oslo, Norway) *(NordiCHI '18)*. Association for Computing Machinery, New York, NY, USA, 286–298. https://doi.org/10.1145/3240167.3240200

[25] Stefan Marks and David White. 2020. Multi-Device Collaboration in Virtual Environments. In *Proceedings of the 2020 4th International Conference on Virtual and Augmented Reality Simulations* (Sydney, NSW, Australia) *(ICVARS 2020)*. Association for Computing Machinery, New York, NY, USA, 35–38. https://doi.org/10.1145/3385378.3385381

[26] Mark McGill, Daniel Boland, Roderick Murray-Smith, and Stephen Brewster. 2015. A Dose of Reality: Overcoming Usability Challenges in VR Head-Mounted Displays. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems* (Seoul, Republic of Korea) *(CHI '15)*. Association for Computing Machinery, New York, NY, USA, 2143–2152. https://doi.org/10.1145/2702123.2702382

[27] Mark McGill, Alexander Ng, and Stephen Brewster. 2017. I Am The Passenger: How Visual Motion Cues Can Influence Sickness For In-Car VR. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems* (Denver, Colorado, USA) *(CHI '17)*. Association for Computing Machinery, New York, NY, USA, 5655–5668. https://doi.org/10.1145/3025453.3026046

[28] Paul Milgram and Fumio Kishino. 1994. A taxonomy of mixed reality visual displays. *IEICE TRANSACTIONS on Information and Systems* 77, 12 (1994), 1321–1329.

[29] David Nahon, Geoffrey Subileau, and Benjamin Capel. 2015. "Never Blind VR" enhancing the virtual reality headset experience with augmented virtuality. In *2015 IEEE Virtual Reality (VR '15)*. 347–348. https://doi.org/10.1109/VR.2015.7223438

[30] Pablo E. Paredes, Stephanie Balters, Kyle Qian, Elizabeth L. Murnane, Francisco Ordóñez, Wendy Ju, and James A. Landay. 2018. Driving with the Fishes: Towards Calming and Mindful Virtual Reality Experiences for the Car. *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.* 2, 4, Article 184 (Dec. 2018), 21 pages. https://doi.org/10.1145/3287062

[31] Krzysztof Pietroszek and Chao Cheng Lin. 2019. UniVResity: Face-to-Face Class Participation for Remote Students Using Virtual Reality. In *25th ACM Symposium on Virtual Reality Software and Technology* (Parramatta, NSW, Australia) *(VRST '19)*. Association for Computing Machinery, New York, NY, USA, Article 97, 2 pages. https://doi.org/10.1145/3359996.3364730

[32] Daniel Pohl and Carlos F. de Tejada Quemada. 2016. See what I see: Concepts to improve the social acceptance of HMDs. In *2016 IEEE Virtual Reality (VR '16)*. 267–268. https://doi.org/10.1109/VR.2016.7504756

[33] Michael I Posner, Mary J Nissen, and Raymond M Klein. 1976. Visual dominance: an information-processing account of its origins and significance. *Psychological review* 83, 2 (1976), 157. https://doi.org/10.1037/0033-295X.83.2.157

[34] Anastasia Ruvimova, Junhyeok Kim, Thomas Fritz, Mark Hancock, and David C. Shepherd. 2020. "Transport Me Away": Fostering Flow in Open Offices through Virtual Reality. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems* (Honolulu, HI, USA) *(CHI '20)*. Association for Computing Machinery, New York, NY, USA, 1–14. https://doi.org/10.1145/3313831.3376724

[35] Rufat Rzayev, Sven Mayer, Christian Krauter, and Niels Henze. 2019. Notification in VR: The Effect of Notification Placement, Task and Environment. In *Proceedings of the Annual Symposium on Computer-Human Interaction in Play* (Barcelona, Spain) *(CHI PLAY '19)*. Association for Computing Machinery, New York, NY, USA, 199–211. https://doi.org/10.1145/3311350.3347190

[36] Pejman Sajjadi, Edgar Omar Cebolledo Gutierrez, Sandra Trullemans, and Olga De Troyer. 2014. Maze Commander: A Collaborative Asynchronous Game Using the Oculus Rift & the Sifteo Cubes. In *Proceedings of the First ACM SIGCHI Annual Symposium on Computer-Human Interaction in Play* (Toronto, Ontario, Canada) *(CHI PLAY '14)*. Association for Computing Machinery, New York, NY, USA, 227–236. https://doi.org/10.1145/2658537.2658690

[37] Thereza Schmelter and Kristian Hildebrand. 2020. Analysis of Interaction Spaces for VR in Public Transport Systems. In *2020 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW '20)*. 279–280. https://doi.org/10.1109/VRW50115.2020.00058

[38] Valentin Schwind, Jens Reinhardt, Rufat Rzayev, Niels Henze, and Katrin Wolf. 2018. Virtual reality on the go?: a study on social acceptance of VR glasses. In *Proceedings of the 20th International Conference on Human-Computer Interaction with Mobile Devices and Services Adjunct - MobileHCI '18*. ACM Press, Barcelona, Spain, 111–118. https://doi.org/10.1145/3236112.3236127

[39] Julie R. Williamson, Mark McGill, and Khari Outram. 2019. PlaneVR: Social Acceptability of Virtual Reality for Aeroplane Passengers. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems* (Glasgow, Scotland Uk) *(CHI '19)*. Association for Computing Machinery, New York, NY, USA, 1–14. https://doi.org/10.1145/3290605.3300310

[40] Keng-Ta Yang, Chiu-Hsuan Wang, and Liwei Chan. 2018. ShareSpace: Facilitating Shared Use of the Physical Space by Both VR Head-Mounted Display and External Users. In *Proceedings of the 31st Annual ACM Symposium on User Interface Software and Technology* (Berlin, Germany) *(UIST '18)*. Association for Computing Machinery, New York, NY, USA, 499–509. https://doi.org/10.1145/3242587.3242630

[41] André Zenner, Marco Speicher, Sören Klingner, Donald Degraen, Florian Daiber, and Antonio Krüger. 2018. Immersive Notification Framework: Adaptive & Plausible Notifications in Virtual Reality. In *Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems* (Montreal QC, Canada) *(CHI EA '18)*. Association for Computing Machinery, New York, NY, USA, 1–6. https://doi.org/10.1145/3170427.3188505