# Simulator Sick but still Immersed: A Comparison of Head-Object Collision Handling and their Impact on Fun, Immersion, and Simulator Sickness

Peter Ziegler[1*] Daniel Roth[2†] Andreas Knote[1] Michael Kreuzer[1] Sebastian von Mammen[1]

[1]Games Engineering and [2]Human-Computer Interaction
University of Würzburg

## Abstract

We compared three techniques for handling head-object collisions in room-scale virtual reality (VR). We developed a game whose mechanics induce such collisions which we either addressed (1) not at all, (2) by fading the screen information to black, or (3) by restricting translation, i.e. correcting the virtual offset in such a way that no penetration occurred. We measured these conditions' impact on simulator sickness, fun, and immersion perception. We found that the translation-restricted method yielded the greatest immersion value but also contributed the most to simulator sickness.

**Index Terms:** Human-centered computing—Virtual Reality; Human-centered computing—Empirical studies in visualization

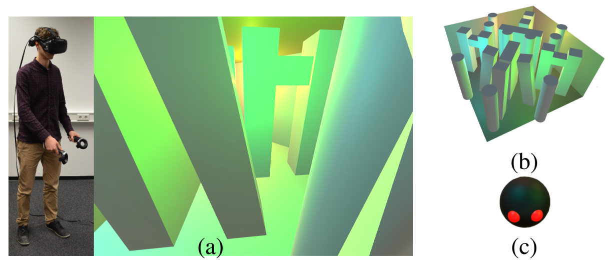


Figure 1: (a) Immersed player (left) and his view in the virtual world (right). (b) Tight corridors promote collisions. (c) Enemies move close to the ground to trigger head movements. Eyes indicate the heading.

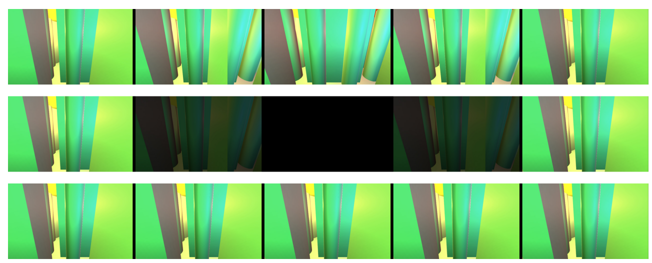

Figure 2: Time slice examples of the three evaluated methods "none" (top), "blackout" (center), "not there yet" (bottom).

## 1 Introduction

A common problem in VR is the handling of collisions between the subject and virtual obstacles. When the subject by accident moves his head into a graphical object, the near clipping plane may intersect with the object, resulting in unintended, unnatural imagery. There are two established alternative approaches to handle this conflict: (1) Doing nothing and accepting a temporarily alienating view, or (2) fading to black for as long as the subject resides in this condition. In this paper, we followed up on the idea of moving the scene to resolve positional conflicts, thereby avoiding any revealing clipping artifacts. Although this approach challenges the best practices against simulator sickness [6], based on a preceding positive experience with a VR game that we had designed that implemented this approach of "collision avoidance", we decided to compare the three approaches not only regarding simulator sickness but also in other dimensions such as fun and immersion.

## 2 Related Work

In order to render the VR experience as enjoyable as possible, it is important to avoid all kinds of disruptions of the generated illusions, i.e., so-called breaks in presence (BIPs) [10]. A high degree of presence can be achieved by coherently integrating visual, haptic and other stimuli [1]. Accordingly, when an actual collision would be expected and instead a clipping artifact is rendered, presence may break. It is the technical incoherence of renderings and expected stimuli that reduces the degree of immersion [9]. Considering head-object collisions, there have been studies on the fear of colliding with other moving objects, investigating the subject's behavior to avoid impending collisions [8, 11]. However, resolving head-object collisions has not been a target before. The general approach of resolving the underlying positional conflict has been proposed, but, to our knowledge, not been pursued with scientific rigor, e.g., [5]. A commercial product that implements a related approach was published while we conducted this study, but not used [2].

*email: peter.ziegler@stud-mail.uni-wuerzburg.de
†email: daniel.roth@uni-wuerzburg.de

## 3 Collision Handling Approach

We implemented three methods to handle head-object collisions. In the "none" method, clipping artifacts become apparent once the user's view is sufficiently close to an object's surface, but no action is taken to mitigate the situation. In the "blackout" method, we fade the screen gradually to black when the player's head starts entering a visual obstacle. When the player's head is fully submerged, the screen is completely black. Clipping artifacts are thus hidden from the user. "Not there yet" is our approach to resolving the underlying positional conflict between the user's head movement in the physical world and constraints in the simulated world. Consider the user's head as a spherical volume that fully contains the frustum's near end. If a collision with an obstacle occurs, a penetration vector is calculated, and its projection on the horizontal plane is added to the user's position. This effectively moves the user away from the object while not hindering any movement in parallel to the obstacle's surface. This resolves the intersection of the head and the obstacle, preventing the player from entering *into* the obstacle.

## 4 Method

The study was conducted using a within-subject's design with the method (none vs. blackout vs. not there yet) serving as factor. We created a VR game using Unity3D and an HTC Vive VR head-mounted display. In the game, the player was chased by multiple enemies in a narrow space, which facilitated frequent collisions between the user and the environment (Figure 1). The enemies randomly either moved directly towards the player or in a random direction. Starting with a single enemy, another one was spawned every minute into the game. The player could instantly teleport by pressing the touchpad of either controller, aiming at a location and releasing the touchpad. The game took place in a small $5 \times 5m^2$ virtual room for 10*min*. The player was informed about his score which dropped upon enemy contact. After pretests and balancing, we had empirically identified a design configuration of the narrow world and the enemy behavior that led to high amounts of collisions for both room-scale movement and teleportation.

We assessed *simulator sickness* [4] in a pre-post measure (0=none, 3=severe; Cronbach's $\alpha$'s 3.86-6.46). We measured *sensory immersion* and *game experience* using the game experience questionnaire (GEQ) [3] in the 3.3 version [7] (1=not at all, 5=extreme; Cronbach's $\alpha$'s >7.10). We measured *enjoyment* using three questions: (1) "I had a good time playing the game," (2) "The game was enjoyable," and (3) "I had fun playing the game." (1=do not agree at all, 7=fully agree). To assess timing effects throughout the time participants were playing the game, we asked the subjects to orally answer questions assessing the current level of *in-situ enjoyment*, *in-situ immersion*, and in-situ sickness. At 3, 6, and 9*min* we asked: 1. Immersion: "Please state how much you feel immersed into the game at this moment?" (1=not immersed at all, 5=very immersed), 2. Enjoyment: "Please state how much fun you have playing the game." (1=no fun at all, 5=very much fun), and 3. Sickness: "Please state whether you are experiencing any sickness." (0=none, 4=severe). We logged the number of collisions, the mean collision time, the total collision time and the overall score in each condition.

The sample included 18 participants (12 female, $m_{age} = 21.47$, $SD_{age} = 2.35$). As sickness effects are highly individual, the same participants were tested in each condition on three consecutive days in repeated measures. The start condition and the sequencing of conditions were randomly assigned. Participants had 6.88 previous VR experiences ($SD = 18.38$). We first asked the pre-experimental demographic questionnaire and SSQ. We equipped the participants with the HMD and informed them about the controls and the goal, which was to avoid the enemies and maximize the score. Participants than played for 10*min* while we asked the in-situ questions and answered the post-experimental questionnaire afterwards.

## 5 Results

We calculated repeated measures ANOVAs with condition and time of measure serving as factors. Regarding simulator sickness, we found a significant interaction effect for the disorientation subscore of (see [4]) ($F(2,32) = 3.843$, $\eta_p^2 = .194$, $p = .032$). Pairwise comparisons showed that only in the "not there yet" condition, the difference between pre ($M = 12.82$, $SD = 4.12$) and post ($M = 31.94$, $SD = 9.22$) measurement was significant. The results for oculomotor, nausea and the toal score were non significant (n.s.). In-situ sickness analyses showed a significant main effect for measurement time ($F(2,32) = 7.051$, $\eta_p^2 = .306$, $p = .003$). Pairwise comparisons showed a significant difference between minute 3 ($M = .08$, $SD = .27$) and minute 6 ($M = .28$, $SD = .493$; $p = .020$) as well as between minute 3 and minute 9 ($M = .35$, $SD = .688$; $p = .008$). Pairwise comparisons showed that mainly the "not there yet" method contributed to these effects (both $p's <= .015$) whereas other comparisons over time in the conditions were n.s. Repeated measures ANOVAs for the in-situ measures showed a significant main effect for fun over time ($M_3 = 3.06$, $SD_3 = 0.76$, $M_6 = 3.26$, $SD_6 = 0.96$, $M_9 = 3.47$, $SD_9 = 1.04$; $F(4,64) = 4.481$, $\eta_p^2 = .219$, $p = .019$). Pairwise comparisons revealed a significant increase of fun between minute 3 and minute 9 in the "none" condition. For all other conditions and measure times, the increase was stable, differences were non significant (n.s.). In-situ immersion analyses showed a significant interaction effect ($F(4,64) = 3.243$, $\eta_p^2 = .169$, $p = .017$). Pairwise comparisons revealed a significant drop in the "blackout" condition between the 3 and 6-minute measure ($p = .028$). Immersion perception in the "blackout" condition then recovered between minute 6 and minute 9 ($p = .030$). A main effect for condition showed that "not there yet" was rated highest ($M = 4.0$, $SE = .15$), significantly higher than "blackout" ($M = 3.51$, $SE = .21$) and higher than "none" ($M = 3.81$, $SE = .17$), but n.s.. We calculated repeated ANOVAs for the collision measures and the scoring. We found significant effects for the number of collisions ($p = .019$), the mean collision time ($p < .001$), and the total collision time ($p < .001$). Pairwise comparison revealed a successful reduction of mean collision time and total collision time ($p's < .001$) as well as a reduction in the number of collisions ($p's < .019$) of the "not there yet" method compared to both other methods, whereas the other methods did not differ significantly. GEQ ratings and player enjoyment were n.s. No further significant effects were found.

## 6 Discussion & Summary

As expected, the "not there yet" condition induced simulator sickness the most. An immediate conclusion in terms of sickness prevention would be to (a) favor scenarios avoiding obstacle penetrations whenever possible, e.g., based on collision avoidance strategies [8, 11], (b) utilise "blackout", if there is an additional benefit, e.g., shielding game contents, (c) disregard the problem and effectively implement the "none" condition. We were surprised that the three methods had no effects on the players' game experience and fun. We assume the increase in in-situ fun is due to the increasing number of enemies over time.

We described the "not there yet" method to avoid revealing clipping artifacts in VR by resolving the underlying positional conflict. We compared it with two established conditions ("none" and "blackout") in terms of simulator sickness, fun, and immersion. Ignoring the problem causes the least complications but it conflicts with the intended view and it does not yield a high degree of immersion. The "not there yet" condition achieved the best immersion values but suffered from an expected drawback in simulator sickness. To join the best of all conditions, we propose investigating a "slices" condition next, which combines the concept of chaperon boundaries and intermittent surface visualizations after penetration.

## References


[1] F. Biocca, Y. Inoue, A. Lee, H. Polinsky, and A. Tang. Visual cues and virtual touch: Role of visual stimuli and intersensory integration in cross-modal haptic illusions and the sense of presence. *Proceedings of presence*, pp. 410–428, 2002.

[2] Gripati Digital Entertainment. Head Collision VR. Software, 10 2017.

[3] W. A. IJsselsteijn, Y. A. W. De Kort, and K. Poels. The game experience questionnaire. Techn. Uni. Eindhoven, 2013.

[4] R. S. Kennedy, N. E. Lane, K. S. Berbaum, and M. G. Lilienthal. Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness. *The international journal of aviation psychology*, 3(3):203–220, 1993.

[5] O. Kreylos. Game engines and pos. head tracking. Doc-OK, 2014.

[6] J. J. LaViola Jr. A discussion of cybersickness in virtual environments. *ACM SIGCHI Bulletin*, 32(1):47–56, 2000.

[7] K. Poels, Y. de Kort, and W. IJsselsteijn. D3.3 : Game Experience Questionnaire: development of a self-report measure to assess the psychological impact of digital games. Techn. Uni. Eindhoven, 2007.

[8] A. Scavarelli and R. J. Teather. VR Collide! Comparing Collision-Avoidance Methods Between Co-located Virtual Reality Users. In *Proceedings of the CHI*, pp. 2915–2921. ACM, 2017.

[9] M. Slater. A note on presence terminology. *Presence connect*, 3(3):1–5, 2003.

[10] M. Slater and A. Steed. A virtual presence counter. *Presence: Teleoperators and virtual environments*, 9(5):413–434, 2000.

[11] N. Sohre, C. Mackin, V. Interrante, and S. J. Guy. Evaluating collision avoidance effects on discomfort in virtual environments. In *Virtual Humans and Crowds for Immersive Environments (VHCIE), 2017 IEEE*, pp. 1–5. IEEE, 2017.