Immersive FPS Games: User Experience and Performance

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ABSTRACT

Computer games are ideally placed to form the content of future Immersive Media, but this prospect is faced with both technical and usability issues. This paper describes an experiment in immersive gaming using a state-of-the-art computer First Person Shooter (FPS) game, in which we analyze user experience and performance through a combination of in-game metrics, questionnaires and subjective reports. We describe the evaluation of a major commercial computer game as a real-time immersive stereoscopic experience based on a four-screen CAVE^{TM}-like installation. The implementation is based on a bespoke VR middleware developed on top of the game's own engine. Our results show an overwhelming subjective preference for the immersive version despite a decrease in performance attributed to a more realistic aiming mechanism. More importantly, metrics suggest that users took advantage of the immersive context rather than simply transposing their desktop gaming skills.

Categories and Subject Descriptors

H.5.1 [**Multimedia Information Systems**]: Artificial, Augmented and Virtual Reality - Virtual Reality for Art and Entertainment

General Terms

Measurement, Performance, Experimentation, Human Factors

Keywords

Immersive Gaming; Virtual Reality; User Experience; Performance; Presence; Cybersickness; Game Engine

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1. INTRODUCTION

The evolution of computer games has been largely driven by the increasing performance of 3D graphics hardware, allowing greater realism and the rendering of more complex scenes. This would naturally lead us to explore how 3D games could further evolve in the future, if they were to evolve into high-end, user-centered, visualization systems traditionally associated with VR. Although there is no shortage of work comparing desktop VR to immersive VR, our focus is specifically on the exploration of how current desktop gaming could evolve into immersive gaming. In this paper, we will use the term *immersion* primarily in its technical acceptation [20], where it refers to the hardware devices that support user-centered visualization (such as surround displays and user tracking). Other authors have used immersion in its more generic meaning, and have for instance related it to desktop displays [24]. Brown and Cairns [2] use the term immersion to describe user experience in games rather than technical implementation, through various degrees of engagement, eventually relating it to the concept of Flow [5], which has also gained popularity to analyze gaming experience [25]. We thus use here the term *immersive gaming* to refer to the deployment of state-of-the-art commercial game titles to an immersive platform such as a CAVE^{TM}[4]. The purpose of the present study is to explore user experience and performance during immersive gaming with a strong user-centric perspective for both visualization and interaction. MacMahan and Bowman [20] describe multiple benefits of immersion, which include: a realistic experience, improved spatial understanding, and increased peripheral awareness. They also discuss the complex relationships between immersion (and some of its determinants such as large Fields Of View (FOV) and stereoscopic visualization) and user task performance. Consequently, our primary objective is to compare user experience and performance in desktop and immersive modes with an comparable game and rendering performance. In this study we focus on FPS games using Unreal® Tournament 3. We explore user experience and performance through a range of typical concepts in the study of computer games: media presence, gameplay performance and engagement, negative effects (e.g. cybersickness) through self-reporting and interaction metrics.

2. RELATED WORK

Several research groups have reported immersive versions of game engines with CAVE^{TM}-like [4] installations. Paul Rajlich's CAVE Quake II, developed at NCSA, is probably the first immersive implementation of a popular computer game. It has been followed by CAVE Quake III Arena, based on the open source Aftershock engine. CAVEUT was originally developed at the University of Pittsburgh [9]. As noted in [12], CAVEUT used an older version of the Unreal® Engine which is now outdated, and has been replaced in the latest release of the game (Unreal® Engine 3). Juarez et al. [12] have ported the CryEngine2 game engine to a CAVE^{TM}-like installation, with their CryVE system. They have reported average frame rates < 20 fps, which may not be sufficient to support high-intensity gaming; in addition they have emphasized multi-user participation over tracking and stereoscopic visualization, somehow weakening the user-centric nature of the system if compared to the original CAVE^{TM}concept. It should be noted that, with the exception of the CAVE Quake versions, the above systems were actually exploiting the game engine itself to support different types of applications in digital arts or cultural heritage. Overall, high-end immersive gaming has not been central to these previous developments, nor has it been the object of extensive usability studies that balance player performance and determinants of experience, both positive and negative. LaViola and Litwiller [16] compared player performance for 2D and 3D stereoscopic single-screen displays with identical input controllers. They concluded that 3D stereoscopy did not significantly improve player performance despite users expressing a preference for it. However, their experiments, which made use of a 50-inch monitor with no motion parallax (head-tracking), did not explore fully immersive, user-centric installations. Zhou et al. [30] compared user performance and preferences across three versions of the same computer game: a desktop version, a VR version using a low-cost Head Mounted Display (HMD) and an Augmented Reality version. Some of their findings may however be difficult to generalize as they used a purpose-built first-person shooter whose gameplay may not correspond to current commercial standards in terms of difficulty, engagement and rendering. Yoon et al. [29] have developed an immersive version of the Unreal® Tournament 2004 FPS (First Person Shooter), using a HMD and comparing a data glove with gesture recognition (from a set of 8 command gestures) against standard keyboard and mouse inputs. They have studied physiological responses and subjective experience, without really assessing performance and gameplay. Recently, McMahan et al. [20] have investigated in detail the impact of display and interaction fidelity on the performance of an immersive (CAVE^{TM}-based) FPS. Despite several interesting findings, one major limitation of their work, in our view, is that they have developed an ad hoc FPS game (using an open source version of the Quake engine), which departs significantly from traditional gameplay. They have, for instance, redesigned simple maps with only one single path from start to finish, have altered the appearance of bots to make them neutral so as to decrease emotional effects, and have redesigned NPC (Non-Player Characters) behavior so as to support experimental goals, rather than natural gameplay. Previous work has also evidenced that visual realism and a large field of view improve Presence [14], and thus should increase user's engagement and enjoyment.

Overall, despite the significant interest that the study of games and game engines in immersive VR has previously attracted, there is still no comparative study of immersive gaming in a desktop vs. fully immersive VR configuration that would simultaneously address media and usability aspects such as satisfaction, engagement, performance or acceptability. This implies, in our view, the need for experiments using a commercial blockbuster title and a subject population that reflects the default mode of consumption for that medium, as well as being able to port the original title to an immersive VR setting without altering its gameplay, other than the user-centric nature of display and controls. We precisely present such an experiment in the remainder of this paper.

3. IMMERSIVE SYSTEM OVERVIEW

We first needed to create a VR version of a game title and subsequently explored user experience in this new immersive version. However, for such experiments to be meaningful, it was essential that the VR setting preserved the original gameplay and the rendering quality implemented in the desktop version, with any difference only attributable to the immersive nature of the VR version. For instance, keyboard and mouse are typically used for aiming and navigating in the desktop version but will be performed with a 3D controller (wand) in the immersive version. This was achieved by actually porting the original game title to an immersive VR platform rather than emulating it through bespoke developments (as was the case in some previous immersive gaming implementations). We used our in-house VR middleware, named CaveUDK [18], modifying the underlying game engine itself without impacting its rendering performance. This VR middleware extends the original idea of [10] to cover the latest version of the Unreal® game engine (version 3) as a source and a 4-wall CAVE^{TM}-like stereoscopic display as the target platform (see Figure 1). Such approach avoids the risk of altering gameplay and rendering performances when importing a game title to an immersive platform. Our VR system is composed of four screens (3.0 m×3.0 m×2.25 m), with a PC-based cluster running Unreal® Clients and Server. It includes real-time head and hand tracking, and supports motion parallax and active

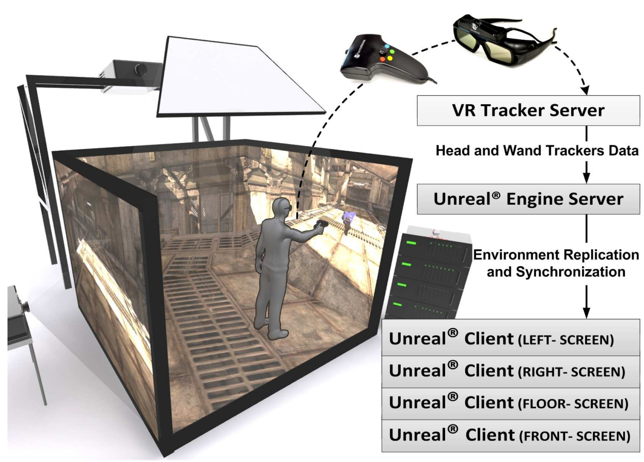

Figure 1: A CAVE^{TM}-based Immersive Gaming Platform

Figure 2: High Performance Graphics Rendering

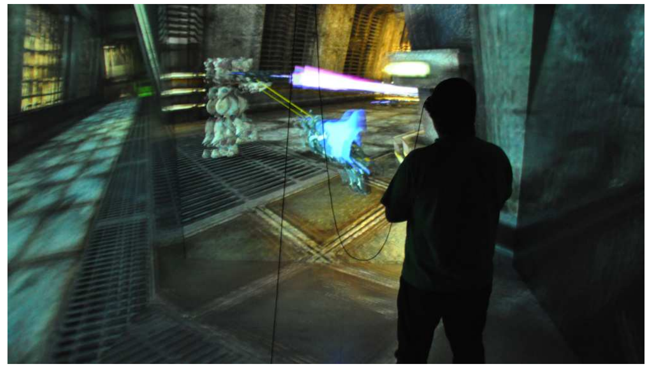

Figure 3: Immersive Gaming Setting

stereoscopic display at up to 50 frames per seconds. Figure 2 illustrates the high performance graphics rendering possible (2M+ triangles per screen per seconds in average) with CaveUDK while preserving frame rate and multiscreen camera synchronisation.

4. EXPERIMENTS

With such a VR platform, we have compared a desktop and immersive version of the Unreal® Tournament 3 game, a popular First-Person Shooter. Both versions of the game were identical (i.e. matching gameplay, rendering performances (50 Hz in 3D) and similar end-to-end latency (<82 ms) [18]), with differences only attributable to the immersive nature of the VR version (i.e. large field of view, active stereoscopy, and wand tracker interactions instead of desktop monitor and keyboard/mouse input). As visible on Figure 2 the player navigates by pointing and pushing the analogue joystick embedded in the wand, a traditional moving-by-pointing metaphor [1]. The left and right position of the analogue stick respectively trigger left and right rotation. The player also aims and fires laser using the wand, on which the virtual weapon was attached (see virtual hand in blue in Figure 3 holding the weapon - yellow ray indicates aiming direction). The player therefore points the wand towards the target through extending his arm, as if using a handgun, and presses the trigger.

Within this experiment, user experience and performance were explored through a combination of in-game metrics, and subjective questionnaires, comparing the commercial desktop version of the game to its immersive version. Beyond the actual technical feasibility of immersive gaming, we wanted to determine the change in user experience caused by high-end, user-centered implementation, as well as user subjective preferences and any limitations, brought by adverse effects. A repeated measures design was used with two levels of a single factor, which we shall call media form (these two levels being Immersive or Desktop). The order of media form presentation was randomly chosen for each candidate in order to minimize any learning curve effects.

Thirty-nine male subjects, aged between 19 and 30 years (mean age 21.54 years) participated in this experiment. Only active and regular gamers were selected to take part. All were familiar with the FPS genre, as our objective was to investigate the acceptance, by a representative sample of gamers, of a more sophisticated, somehow extreme, technical setting. Criteria for selection included average time spent playing per week: these were later confirmed by the high average scores with over 20 NPCs killed in a 5-minute session, achieved in the desktop configuration. The sample can be considered representative of FPS player population, which has been shown to be predominantly male [11] (with only 2 % of female players on average). The average duration of a session was 45 minutes (including filling questionnaires). Participants were allowed to discontinue the experiment at any time if they experienced any major discomfort.

The choice of the FPS genre was dictated by several criteria: the need to measure objective in-game performance, the existence of a well-defined audience, and the importance of spatial aspects with a first-person view. In addition, Nacke and Lindley [21] have suggested that the study of FPS games may simplify the investigation of presence. One possible objection to the use of FPS for enjoyment experiments is that their violent content would constitute a major determinant of user experience, raising questions on the generic nature of our potential findings. However, [23] have shown that in FPS, enjoyment was determined by the experience of autonomy and competence during gameplay and that violent content did not actually contribute significantly to it.

4.1 Procedure

The experimental task consisted of a short 5-minute FPS "Death Match" game evaluated under both immersive (Figure 3) and standard desktop settings. The independent variable is thus the level of physical immersion whereas dependant variables are: the user's performances, enjoyment, psychological immersion and preferences. To a certain extent, the desktop configuration represented our control condition. Only the screen surfaces and (controls) input system differed between the two configurations where the wand tracker replaced the traditional keyboard/mouse controls. The user wore RF shutter glasses equipped with a head tracker (Figure 1), and used the hand-held wand tracker for navigation and interaction. Concerning the display device, the desktop setting relied on a standard 19 inch non-stereoscopic monitor. The experiment consisted of three main parts: i) Experiment introduction (∼ 5 minutes); ii) Desktop session (∼20 minutes); iii) CAVE session (∼20 minutes), the order of the latter two being attributed randomly.

Participants were first asked to confirm the absence of any (a) history of seizures, epilepsy, or inner ear / vestibular disorders and (b) type of intoxication, psychotropic medications, or substances that can alter vigilance. For both configurations, subjects were offered a practice session to get acquainted with navigation and interaction with this particular type of game level and more specifically wand tracker controls. During this session, they were gradually introduced to: i) Navigation controls: how to walk and turn and ii) Interaction mechanisms: how to aim and shoot at a NPC. However, during this briefing great care was taken neither to disclose how users may actually maximize their scores under both settings, nor to demonstrate the use of immersive gaming by an experienced user.

4.2 Measures

Recently, evaluations of gameplay experience, and the identification of its determinants, have attracted significant research interests [15] [19]. The majority of recent studies relied on both objective and subjective measurements in order to measure user's experience and performances. In-game metrics are notably used as objective measures to qualify the user's engagement [3]. Following a similar approach, for each session, user's interactions, navigation, and field of vision were constantly logged under the form of in-game metrics. We have qualified these metrics as *Interaction* metrics as they reflect both user's performance and engagement. They have been divided into three main categories:

m1: *In-game Performance*: These metrics mostly record player's accuracy (% of miss and hit shots), score (number of player deaths, number of kills (aka *frags*) and attack direction and distance (% of shots facing the opponent, distance to opponent, percentage of time having an enemy in the user's FOV).

m2: *In-game Navigation*: These metrics collect data on the distance covered in the virtual environment as well as average camera rotation speed and jump frequency.

m3: *Multiscreen Usage*: These metrics includes percentage of time spent per screen, and frequency of point of view changes. The CaveUDK monitoring tool constantly records the user head orientation and position to extract the current zone viewed.

These objective measurements should indicate if users take advantage of the large field of view and 3D rendering to navigate and interact efficiently. The degree of appropriation of the immersive setting affordances should therefore be reflected by these metrics. They should reveal if users took advantage of the immersive context rather than simply transposing their desktop gaming skills. They will in turn be related to the analysis of subjective user experience mirroring user's satisfaction, immersion and cybersickness. Regarding subjective measures, participants were also requested to complete three questionnaires immediately before and after each session. Participants completed the Simulator Sickness Questionnaire (SSQ), developed by Kennedy et al. [13]. At the end of each session, users completed the ITC-SOPI Presence questionnaires proposed by Lessiter et al. [17]. Participants were also able to express their preferences, and free to comment on their experience in a separate form. Additional questionnaires have been considered such as PENS (Player Experience of Need Satisfaction) [22], PIFF (Presence Involvement Flow Framework). However, the ITC-SOPI questionnaire has been employed in both games and immersive VR studies [6] providing an appropriate way to evaluate user experience in immersive gaming.

5. RESULTS AND DISCUSSIONS

5.1 User Preferences

Our results demonstrate a strong preference of users for the immersive setting (72 %), which is also clearly confirmed by their self-reporting such as:

- *"It felt like I was in the game rather than just playing it; felt much more immersed "*
- *"The immersion was so complete that towards the end of the second round, I forgot the walls were separated and just saw the environment around me"*

Only 17 % of comments included negative aspects which mostly refer to disorientation; such as *"The CAVE made me feel really dizzy""*. Some comments also expressed certain difficulty towards the controls: *"Whilst difficult to control, it was much more engaging than PC screen"*. Immersive experiences have been qualified as more intense in users' self-reports, despite the challenge of adapting to new game controls (3D controller such as wand). This preference contrasts with a higher performance level in the desktop configuration, a finding which is however consistent with previous literature [15].

5.2 In-Game Navigation

User *In-game navigation* metrics are indicators of spatial behavior as well as being strongly related to gameplay and playing style. We found that users travelled similar distances within the game world in both settings. The overall distance covered between two player's deaths is 630 m in the immersive setting and 840 m in desktop, with a maximum avatar ground speed of $9\,\mathrm{m\,s^{-1}}$ over a map dimension of about 10 800 m (60 m×60 m×3 floors). The average walking distance is 24.4 m for the immersive and 27.8 m for the desktop. The slight difference in terms of distance covered could also be related to a tendency to jump at least 3 times more under desktop setting. The difference in term of the user's camera average rotation speed: $5.09\,^\circ\,\mathrm{s^{-1}}$ in the desktop version compared to $3.50\,^\circ\,\mathrm{s^{-1}}$ in the immersive one, can be analyzed by taking into account the respective FOV. The product of $rotationspeed \times FOV$, which is an indication of how the user explores his environment, is comparable in both settings ($140^\circ \times 3.50\,^\circ\,\mathrm{s^{-1}} = 490\,^{\circ 2}\,\mathrm{s^{-1}}$ against $90^\circ \times 5.09\,^\circ\,\mathrm{s^{-1}} = 458.1\,^{\circ 2}\,\mathrm{s^{-1}}$ in desktop).

5.3 Multiscreen Usage

Interestingly, the majority of the participants seem to adapt almost immediately to a large field of view as users were facing at least two screens 40 % of the time and switched screen on average 25 times per 10 minutes session. This high frequency of head movements could be related to the fast-paced gameplay of FPS game, forcing the player to be either in constant motion or monitoring multiple directions at any time, as this is made easier in the immersive setting.

5.4 In-Game Performance

The goal of such game is to kill (aka *frag*) as many other players (aka *bot* or NPC) as possible within a certain time limit while evolving in combat arena (aka *map*).

Therefore, player's performances could therefore be measured in terms of number of other players killed and number of deaths. The former demonstrates the accuracy of the

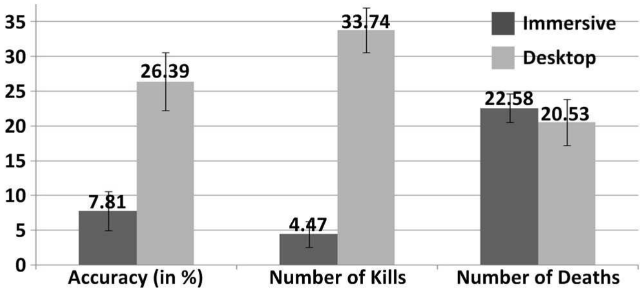

Figure 4: Immersive vs. Desktop Performances

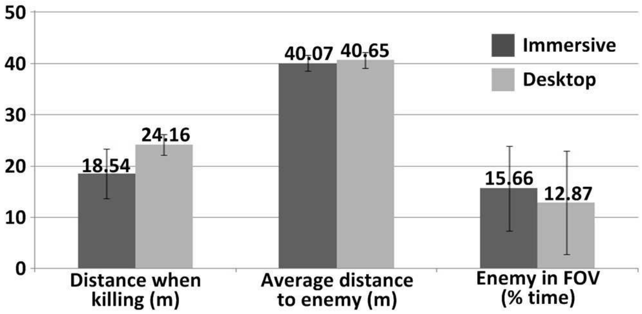

Figure 5: Aiming and Shooting Metrics

player, while the latter relies on the movement agility to avoid projectiles. In-game performance (scoring and aiming) was significantly higher for the desktop configuration. Paired samples t-tests were run on performance data relating to game metrics. The results showed that the immersive condition resulted in significantly lower performances than the desktop condition on accuracy ($t(39)$=−13.76, $p < .001$), number of kills ($t(39)$=−21.032, $p < .001$) and for the number of deaths ($t(39)$=3.53, $p < .01$). A finding that can largely be attributed to a difference in control devices. As expected, most subjects reported the difficulty to aim with a 3D wand tracker rather than with a mouse resting on a fixed surface. As shown on Figure 4, the average score for the desktop setting was around 33.7 kills (with an accuracy of 26.4 % for 77.9 shots) compared to only 4.47 kills (with an accuracy of 7.81 % for 29 shots) in the immersive version, clearly explaining the difference in score by the relative accuracy of the aiming device. This is also confirmed by the fact that shooting distances (Figure 5) are smaller in the immersive version (18.5 m) than in the desktop version (24.2 m). The close percentages of time having an enemy in the FOV (15.7 % and 12.9 %) also suggest a lack of accuracy rather than navigation difficulty or lower target detection. This is consistent with previous research that has established the greater accuracy of the 2D mouse for desktop 3D pointing [26], within an FPS context [8]. Previous work has also suggested an interpretation of the increased difficulty of 3D pointing in terms of Fitt's law [7], with a participation of hand tracking lag in 3D [27].

5.5 User Experience

The ITC-SOPI scores also reveal a higher degree of spatial presence (3.5 compared to 2.56) within the immersive version. Results for all four subscales confirmed that significantly higher presence related ratings were given for the immersive setting compared with the desktop setting: Spatial Presence ($t(38)$=9.51, $p < .01$), Engagement ($t(38)$=3.59, $p < .01$), Negative Effects ($t(38)$=9.10, $p < .01$) and Ecological Validity ($t(38)$=6.65, $p < .01$) which is representing the perception of the virtual world as a physical and believable reality. The immersive configuration seems to inherit the traditional cyber-sickness symptoms, while remaining moderate in our case, with only 12 % difference between total SSQ scores. Our results are in line with expectations, with the immersive configuration producing higher scores on spatial presence and ecological validity, and a slightly higher occurrence of cybersickness. In addition, Wirth et al. [28] have shown that spatial presence can intensify existing media effects such as the enjoyment of digital entertainment, suggesting a possible leverage effect on user preferences.

6. CONCLUSIONS

We have described the transposition of a state-of-the-art commercial computer game into a fully immersive VR setting. Unlike previous attempts, this implementation is fully consistent with the original gameplay and achieves real-time stereoscopic rendering with motion parallax at an average frame rate of 50 fps. This immersive gaming implementation only differs from the original game in its user-centric nature, which offers new modalities of interaction. We explored user interaction, in-game performance, and overall experience in that setting. Subjects quickly adapted to the user-centric nature of the environment as evidenced by their visual exploration patterns (use of multiple screens, screen selection, etc.) and navigation metrics (distance covered, rotation speed, etc). We also observed an interesting dissociation between in-game performance and player satisfaction, where players expressed a clear preference for the immersive setting, despite a lower aiming accuracy also deriving from the user-centric nature of the game controls. Their study, Klimmt et al. [15] have also established that in-game FPS performance was not a major determinant of enjoyment. One limitation of our study is a technical one and rests with the VR devices: the wand buttons response time is inferior to that of a mouse, and our devices were not wireless, which may have impaired some of the players' movements. This work has shown that immersive gaming has the potential to rapidly provide a higher level of enjoyment to regular gamers, even if its improved realism results in a decrease of in-game performance and requests further physical efforts. Further work would explore how to restore part of this performance, for instance through more responsive input devices and appropriate navigation/interaction techniques.

7. ACKNOWLEDGMENTS

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