VIRTUAL REALITY 3RD PERSON CAMERA BEHAVIOR MODES

Daniel P. O. Wiedemann
Department of Media
Middlesex University
The Burroughs, London, NW4 4BT
United Kingdom
E-mail: d.wiedemann@mdx.ac.uk

Peter Passmore
Department of Computer Science
Middlesex University
The Burroughs, London, NW4 4BT
United Kingdom
E-mail: p.passmore@mdx.ac.uk

Magnus Moar
Department of Media
Middlesex University
The Burroughs, London, NW4 4BT
United Kingdom
E-mail: m.moar@mdx.ac.uk

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ABSTRACT

We describe and evaluate five different level design independent modes of handling camera behavior in the 3rd person game LizzE – And the Light of Dreams in Virtual Reality. The behavior of the different modes will each be illustrated in detail. To evaluate the modes A: *Fast circling,* B: *Lazy Circling,* C: *No Circling,* D: *Blink circling* and E: *Buffered pulling,* an experimental study with 33 subjects was conducted. An analysis of the resulting data will show why *Buffered pulling* seems to be the most promising of the examined modes. We elaborate on the quantitative and qualitative hybrid experiment design and methodology. Eventually the advantages and disadvantages of the five tested modes are discussed in terms of supporting the gameplay, player enjoyment, in game performance and the tendency to induce nausea.

INTRODUCTION

When conceiving a Virtual Reality (VR) game, one might quickly think of digital games in 1st person perspective because of the fundamental properties of VR Head Mounted Display (HMD) technologies. At this point the essential properties focus on translating the natural movement and rotation of the human head into the application. But VR games offer more than just the ability to intuitively move the head of the playable main game character. Among other possible game genres, 3rd person perspective games bring up interesting gameplay and design opportunities (e.g. having to look around a corner for the main character or various forms of communication between characters and the player entity/the stereo camera rig). However 3rd person perspective VR also poses significant challenges in terms of camera behavior. The critical need to avoid nausea or simulator sickness opposes most formerly traditional techniques of moving the camera in relation to the main character. Getting the camera movement and rotation right (Hurd and Bettner 2014) for the majority of players is crucial for engaging them in the game and prolonging play in the virtual environment. This becomes even more important when developing games for VR, as people tend to experience nausea more quickly and with increased intensity when wearing an HMD. For these reasons we wanted to explore the question: "In which ways can 3rd person VR games work for a broad audience?"

To evaluate different camera behavior approaches in 3rd person VR in a "lifelike" manner, we decided to utilize a realistic use case. As complete source code access was a requirement, we chose LizzE – And the Light of Dreams as our primary game platform (see Figure 1) (FIERY THINGS 2013). To provide reliable and reproducible results in terms of damage points inflicted by attacks, we modified this hack and slay game to resign of any corresponding random range behaviors.

For VR applications, it is important to provide a high and steady frame rate. By removing some effects and lowering the default rendering quality, we achieved steady 60 fps in VR mode, with enough buffer to cope with any possible spikes in performance usage. Though relatively low at this point (Oculus recommends 90 fps for their upcoming CV1 HMD), this frame rate also made screen mirroring and thus the parallel video recording of the user and the game possible for our experiment setting. Furthermore, the camera behavior modes we wanted to explore in this experiment, should be level design independent and only relying on their algorithms and not manually placed waypoints or similar strategies. Hence, the relatively unrestricted, in all directions explorable level design was kept for the user test as is.

The remainder of this paper is structured into six different sections. The section "Related Work" will consider related work of this field. In the section "Experiment Methodology" we will describe the details of how the experiment was conducted and which observable variables were gathered per participant. The section "Camera Behavior Modes" will illustrate the different approaches of the five camera modes. We will list the extrapolated findings from the data in the section "Results". In the section "Conclusion" we will elaborate on our interpretation of these findings. Based on the tested camera behavior modes and our findings about them, we will offer developers an implementation recommendation. The section "Future Work" will cover possible next steps in research and implementation.

RELATED WORK

Reducing nausea and simulator sickness while maintaining an attractive gameplay does not only pose challenges for Virtual Reality, but for other sorts of developments too. The experiment on "Altering Gameplay Behavior using Stereoscopic 3D vision-based video game design" (Schild et al. 2014), explored among other topics, the effect of stereoscopic 3D on simulator sickness of subjects, while playing a 3rd person flying game, either in "side-scrolling view" or "behind-view" perspective. Schild et al. did not register a

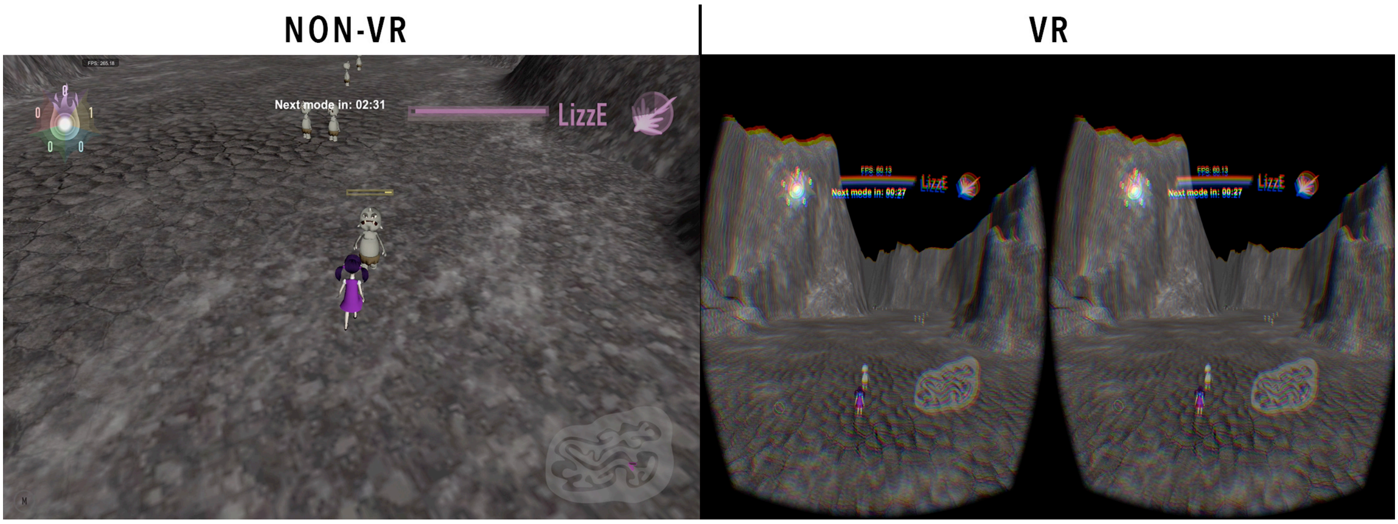

Figure 1: Screenshots of LizzE – And the Light of Dreams, Non-VR Version (left) and VR Version (right)

significant impact on simulator sickness, when using a constant perspective with an UI optimized to reduce parallax changes in vision, while using the side-scrolling view without a constant change in depth animation. The behind-view with a lot of depth animation on the other hand, did show an impact on simulator sickness (Schild et al. 2014).

In terms of very detailed evaluation of simulator or motion sickness in the aeronautic industry, the Simulator Sickness Questionnaire is widely used (Kennedy et al. 1993). It features 16 different questionnaire items on a scale of 0 to 3, which result in the two latent variables "Nausea" and "Oculo-motor" (Kennedy et al. 1993).

In "The Benefits of Third-Person Perspective in Virtual and Augmented Reality?" the advantages and disadvantages of third person and first person views are compared in the context of Augmented and Virtual Reality (Salamin et al. 2006). They argue that, 3rd person perspective is usually preferred by users "for displacement actions and interaction with moving objects while the 1st person view is required when we need to look down or just in front of us for hand manipulations with immobile objects" (Salamin et al. 2006). Furthermore, 3rd person view seems to improve evaluation of distances and the anticipation and extrapolation of the trajectory of mobile objects. This seems to be due to the "… larger field of view provided by the position of the camera for this perspective. The user can thus better appreciate the situation and the distance." (Salamin et al. 2006).

Other studies support the notion, that the reduction of perceived self-motion illusions ("vection") (Riecke and Feuereissen 2012) seems very important when trying to reduce nausea (Yao 2014). Switching from passive observation to actively controlling locomotion significantly impaired vection, as vection onset latencies were raised and vection occurrence was reduced (Riecke and Feuereissen 2012). However, Riecke and Feuereissen's experiment also showed that the relevant parameter to reduce vection was not interactivity in general, but instead the specifics of the active motion control used (a Gyroxus motion chair for some sort of flying simulation). This seems to imply the benefit of using more natural inputs instead of metaphorical devices like joysticks or gamepads.

The game studio Playful (2016) recently released the popular 3rd person VR game "Lucky's Tale", a game very much in the spirit of Super Mario 64 and Banjo-Kazooie (Hurd and Reiland 2016). While developing the game, they were trying different approaches of creating an attractive gameplay and level design but also reducing the possibility for nausea to a complete minimum. Their solution was a combination of reducing user locomotion in general, mostly aiming locomotion away from the user and a clever more linear level design that does not require a lot of turning around (Hurd and Bettner 2014; Hurd and Reiland 2016).

Additionally to the pure functionality and usability of camera behaviors for users, they certainly also drastically affect the visual style of a medium. In filmmaking, camera movement is used to control pace, point of view and rhythm in a scene (Joshi et al. 2014). By manipulating camera movement, viewers or users can be pulled into scene or get disconnected from it and its characters (Joshi et al. 2014). Furthermore, "Camera motion, as a stylistic choice, is often so powerful that it can be the primary memory of a film or video …" (Joshi et al. 2014), or other medium. For experimental design reasons, we did not examine these stylistic characteristics though.

LizzE – And the Light of Dreams did not offer any cut scenes or interactive dialogues in the context of this experiment. But as these possible game aspects are often occurring, further research is needed on how to implement these, specific for VR. In a non-VR context, Galvane et al. (2014) looked into narrative-driven camera control to create cinematic replays of digital games, with little to no manual adjustments. Instead of using an idiom-based technique, as in a stereotypical way of shooting a specific action, their approach is independent of the type of action happening (Galvane et al. 2014). Their technique is reliant on a certain game engine, specialized on dialogue and the computation and interpretation of importances of dialogue parts. Though this approach seems highly reasonable for dialogue heavy games, it comes with the requirement of manually extending the meta data to the dialogues and the related game engine. "Using a physically based model to control cameras offers a practical way to avoid unrealistic camera movements and ensures continuity." (Galvane et al. 2014) seems like an interesting technique for camera movement, which also might be viable for VR, though would need further research.

Reviewing related work has shown a lack of literature in the specific area of camera behavior modes in Virtual Reality. Our study will step in this gap, illustrate several approaches and evaluate them.

EXPERIMENT METHODOLOGY

The experiment hardware setting consisted of one Apple MacBook Pro (Mid 2012) with 2.6 GHz Intel Core i7 CPU, 16 GB RAM and NVIDIA GeForce GT 650M graphics card. As the primary input device we used a Microsoft Xbox 360 controller and for the HMD the Oculus Rift Developer Kit 2 (DK2) and corresponding position tracking camera. The experiment software was using the Oculus Runtime and SDK for OS X v0.5.0.1-beta and was running on OS X v10.11.5. Furthermore were all user test sessions video recorded with a common video camera.

The subjects were verbally and textually informed of possible health and safety issues, as well as the ethical usage of their data in the context of this research. By filling out the first part of a questionnaire, the participants agreed to the experiment terms and provided basic information about themselves and their experience with digital games and VR. The main goal for the subjects was communicated as eliminating as many enemies as possible, while themselves maintaining as much health as possible (see Figure 2). Furthermore, it was made clear that for experimental reasons, the participants could not die in game.

Figure 2: Experiment Application's first Screen

The procedure of the user test is explained to users as following: The experiment will go through six different modes. Each will last for 3.5 minutes and reset the game automatically afterwards, resulting in a total session duration of ~21 minutes.

The first mode will be non-VR and use the default camera behavior, so subjects can make themselves familiar with the original game first. Subsequently the five different camera behaviors will be tested in VR. The order of these modes will be pseudo random after a Latin square sequence for each participant. Between each mode, users are presented a screen showing the identifying character and title of the mode about to start (e.g. "Mode A: Fast circling"). Additionally, while playing, a countdown is visible, showing the remaining time of the current mode. Once all modes are finished, participants take off the HMD and are presented with the session specific order of the modes. This helped the subjects remind themselves when filling out the remainder of the questionnaire. A shortened example of the procedure and the different camera behaviors can be watched at: https://vimeo.com/wiedemannd/vr3rdpersoncamerabehaviors

In the questionnaire, subjects were asked about all VR modes on a 7-point Likert scale if they enjoyed e.g. "Mode A: Fast circling" and in a separate question if it supported their gameplay. Furthermore, they had to directly specify their preferred mode for the game LizzE – And the Light of Dreams and their preference "in general". Two free text questions asked about "How did certain VR camera behaviors affect the way you played the game?" and "Any thoughts about the different VR camera behaviors?". Finally, subjects were asked "Did you feel any nausea during the test, or right afterwards?" on a scale from 0 to 10. Due to the experiment design, nausea could not be ranked separate for each mode directly. This and the availability of previous data on a scale from 0 to 10 resulted in using this simpler nausea evaluation, compared to using the more complex Simulator Sickness Questionnaire (Kennedy et al. 1993).

Additionally, participants and their gameplay were video recorded during their session to capture any verbal remarks and gaming behavior.

Furthermore, aside from the mode order, the experiment application tracked the following in game parameters for each session per mode: *dealt damage, lost health, dealt damage/lost health ratio, kills, pseudo deaths and kills/pseudo deaths ratio.* From this data the following variables were extrapolated: *1st best VR mode in dealt damage/lost health, 2nd best VR mode in dealt damage/lost health, worst VR mode in dealt damage/lost health, 1st best VR mode in kills/pseudo deaths, 2nd best VR mode in kills/pseudo deaths* and *worst VR mode in kills/pseudo deaths.*

CAMERA BEHAVIOR MODES

All tested camera behavior modes are level independent and thus only relying on their individual algorithm. Due to the nature of the game LizzE – And the Light of Dreams, a reduction of depth animation, as described by Schild et al. (2014) was not feasible.

The following illustrations and visualizations will describe the different modes on the X-Z coordinate plane.

To simplify visualizations, a *VR Rig* symbol was used, which stands for two cameras that render a stereoscopic and for VR optimized image to the screen (see Figure 3). The *VR Rig* also generally supports and handles 360° X-Y-Z head rotation and X-Y-Z head position translation (limited by the DK2's position tracking camera's frustum and distance). The playable main character is symbolized by the *Char* figure and looks into the direction its arrow is pointing to on the X-Z plane.

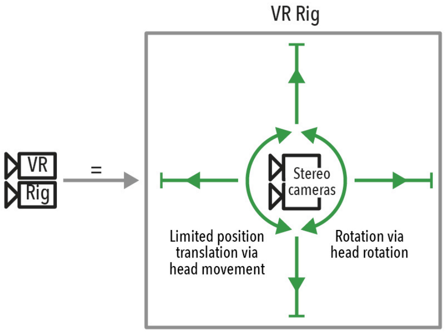

Figure 3: Explanation for VR Rig Symbol

Mode A: Fast circling

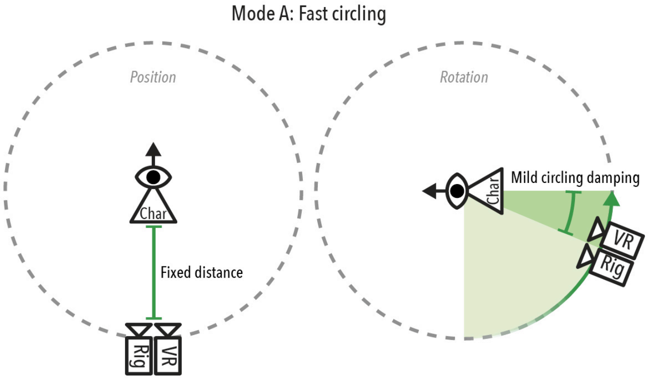

Figure 4: Mode A: Fast circling Visualization

Fast circling, which is also the default camera behavior mode of the original non-VR game, is based on Unity's standard asset ThirdPersonCamera controller from 2013. The *VR Rig* is attached to the main character in a fixed distance. Moving the character into any direction immediately pulls or pushes the *VR Rig* with it. Turning the character will quickly circle the *VR Rig* in an animated way behind the character again with a mild damping (see Figure 4).

Mode B: Lazy circling

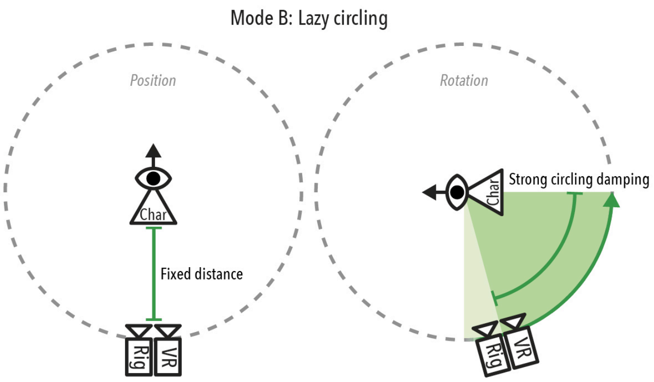

Figure 5: Mode B: Lazy circling Visualization

Lazy circling uses the same algorithm as *Fast circling,* only with partly different parameters. When rotating the character, the *VR Rig* circles slowly behind the character again. This is accomplished by adjusting the parameters angularSmoothLag from 0.2f *(Fast circling)* to 2.8f and angularMaxSpeed from 100f *(Fast circling)* to 18f. This results in a clearly stronger circling damping (see Figure 5).

Mode C: No circling

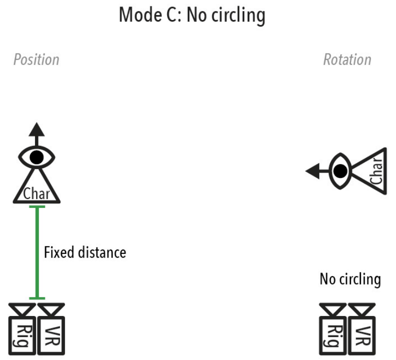

Figure 6: Mode C: No circling Visualization

No circling has the same fixed distance and position translation behavior to the main character as modes A and B do. The difference is the *VR Rig* does not circle around it, when turning the character (see Figure 6).

Mode D: Blink circling

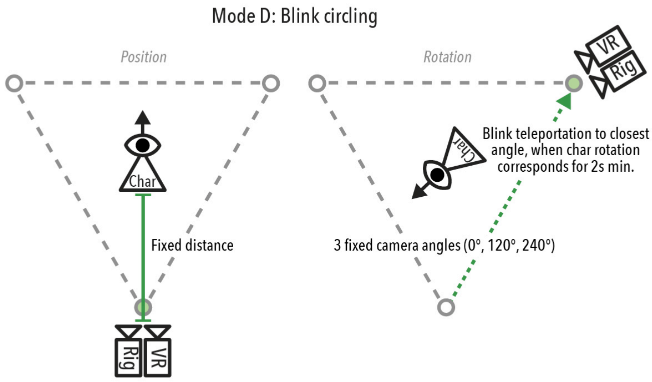

Figure 7: Mode D: Blink circling Visualization

Blink circling as the modes A, B and C keeps the same fixed distance and position translation behavior to the main character. The circling is restricted to three evenly distributed and fixed camera angles around the main character at 0°, 120° and 240°. When turning the character, no immediate circling is performed. Only after the character's rotation corresponds to a new angle for more than 2 seconds a blink will be performed. In a blinking manner, the screen will very quickly fade to black. Then the *VR Rig* will be teleported in a non-animated way to the corresponding position and turned in the corresponding direction (see Figure 7). Afterwards the screen will very quickly fade back to the game environment. The complete duration of this process takes 0.25 seconds and feels very much like a blink.

Mode E: Buffered pulling

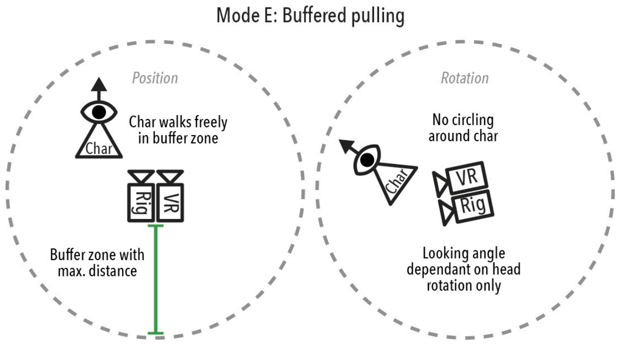

Figure 8: Mode E: Buffered pulling Visualization

Buffered pulling uses a very different approach. The character does not keep a fixed distance to the *VR Rig,* but can instead walk freely inside a buffer zone around the *VR Rig* without pulling or pushing it. Once the character reaches the border of the buffer zone, the *VR Rig* will get pulled with it, like on a leash. Turning the character has no effect at all on the rotation of the *VR Rig.* The user needs to physically turn (e.g. preferred in a swivel chair or standing), in order to look at the character, when it walks into a very different direction (see Figure 8).

RESULTS

The experiment was conducted with 33 participants (total n = 33), from which 23 were male and 10 were female. Ages ranged from 26 to 76 years and averaged at 31 years. According to the statement "I am an experienced digital game player", 19 were rather inexperienced (< 4 on 7-point Likert scale) and 14 rather experienced (>= 4) subjects, with a mean of 3.39. Rather little experience with VR noted 27 (< 4 on 7-point Likert scale) and rather more experience with VR only 6 (>= 4) of the participants, with a mean of 2.33. 17 subjects noted, they were playing digital games between "less than once a year" and "once every some months", whereas 16 noted they would play digital games between "once a month" and "every day".

The answers to the direct question "Which VR camera behavior did you prefer (specific for the game LizzE)?" ranked mode A: *Fast circling* on the first place with 30.3% and mode E: *Buffered pulling* on the second place with 27.3%. Whereas the answers to the direct question "Which VR camera behavior did you prefer (in general)?" ranked mode A and E together on the first place with 24.2%. As will be described later on, these results need to be interpreted with great care though. For a full comparison of the answers to these two questions see Table 1.

Table 1: Directly chosen Camera Behavior Mode Preference

	LizzE	In general
Mode A: Fast circling	30.3% (10)	24.2% (8)
Mode B: Lazy circling	18.2% (6)	18.2% (6)
Mode C: No circling	9.1% (3)	18.2% (6)
Mode D: Blink circling	15.2% (5)	15.2% (5)
Mode E: Buffered pulling	27.3% (9)	24.2% (8)

Two chi-square goodness-of-fit tests (Laerd Statistics 2015a) were conducted to determine whether an equal number of participants would choose either mode A, B, C, D or E as their LizzE specific and general preference. The minimum expected frequency was 6.6 in both cases. The chi-square goodness-of-fit tests indicated that the distributions of mode preference by participants in this study were not statistically significantly different (LizzE specific: $\chi^2(4) = 5.030$, p = .284, general: $\chi^2(4) = 1.091$, p = .896). Two additional chi-square tests were conducted with combined data of mode A + B, because of their similarity and mode C, D and E against a distribution of equal proportions for LizzE specific and general preference. The minimum expected frequency was 8.3 in both cases, due to the reduction from 4 to 3 degrees of freedom. In the case of LizzE specific preference, the chi-square goodness-of-fit test indicated that the distribution of mode preference in this study (with combined mode A + B data) was statistically significantly different ($\chi^2(3) = 11.970$, p = .007). In the case of general preference, the chi-square goodness-of-fit test indicated that the distribution of mode preference in this study (with combined mode A + B data) was not statistically significantly different ($\chi^2(3) = 5.909$, p = .116).

Though *Fast circling* was ranked very high as a directly chosen preference, it scored last rank with a mean of 3.15 on a 7-point Likert scale, when asked if participants actually enjoyed using it. Some subjects specifically noted increased simulator sickness, the need for heavy concentration, the need to actually close the eyes while circling and avoidance of rotation altogether. Furthermore, one participant had to completely discontinue the experiment while playing in *Fast circling.* Other subjects described it with the following words: "… extremely nauseating, after this mode all other modes were affected", "… is nearly impossible to play for a longer time (motion sickness).", "… very unpleasant." and "… was 'too fast' / confusing for an inexperienced player". Only four participants noted something positive for this behavior mode, mostly because it was similar to traditional non-VR behavior. *Fast circling* was also clearly ranked last in in game performance when comparing the *dealt damage/lost health ratios* (by 42.42%) and *kills/pseudo deaths ratios* (by 36.36%).

Lazy circling ranked better than *Fast circling* in terms of enjoyment (mean of 4.09) and support of gameplay (mean of 4.15). Though some described it as pleasant, still similar sometimes strongly nauseating effects were observable during other user sessions. One subject described it with the following words: "I didn't like lazy circling and I see no use for this mode, especially while playing a fast game like hack&slay …".

The data shows that participants with VR experience (>= 4 in 7-point Likert scale; n = 6) were more likely to directly choose *Fast* or *Lazy circling* as preference for LizzE (83.33%) and in general (66.66%). The same is true, when looking at the direct choice of preference for LizzE (64.29%) of participants with gaming experience (>= 4 in 7-point Likert scale; n = 14).

In the context of an, in all directions freely explorable level, *No circling* understandably ranked last in support of gameplay (mean of 3.15). Subjects mention the uselessness of this mode when in need of turning, because of the level design: "… made it nearly impossible to play the game properly, because you can't always see the enemies / bullets", "I was a bit lost in no circling camera view because I couldn't see the way. So I tried more to focus [on] the way than on the enemy.", "Mode C is unplayable" and "… bad for orientation. Couldn't see the enemy.".

Blink circling leads the ranking in in game performance. With 27.27% each, it scored the best and second best rank in *dealt damage/lost health ratios* and with 36.36% the best rank in *kills/pseudo deaths ratios.* Opinions about this mode were mixed: "Blink circling was most comfortable as I didn't feel dizzy." and "blink circling was the most comfortable …". But subjects also mentioned disorientation through blinking, the need for heavy concentration and blinks feeling too random: "… seemed more like a handicap to me, because it seemed to happen randomly", "The blinking-mode was ok at some spots but worst at others.", "I did not like and understand the Blink Circling because it didn't feel natural to me. The game just forced a different camera angle on me, abruptly.", "… spontaneously switching the point of view. That was absolutely weird." and "Blink Circling very abrupt, unexpected change of view". Because of the orientation problems, it does not come unexpected that *Blink circling* ranked second last in support of gameplay (mean of 3.6), one rank above *No circling.*

Buffered pulling clearly scored first ranks in player enjoyment with a mean of 4.48, as well as support of gameplay with a mean of 4.27. Most participants mention their delight about the need to physically turn. Participants mostly described this camera behavior mode as very pleasant and really enjoyable. Some furthermore noted: "The buffered pulling mode seemed more intuitive to me …" and "buffered pulling was the most realistic one". The more critical participants mentioned sometimes losing sight of the main character and the inherent issues of physically turning, like pulling cables and the requirement for either a swivel chair or to stand up: "… a little obstructive because I ran out of my field of view sometimes", "Having to stand up and completely turn around to make the camera turn was gameplay wise rather hard to do since I just sat on a couch.", "With [mode] E the gaming experience was different and not so easy.", "Buffered pulling [was] only bad when [the] character is in the center and one has to look downwards.", "Buffered pulling was much more difficult, as I always had to look around to find the character and the cable of the glasses as well as sitting on a [swivel] chair was not optimal." and "Freedom of movement was limited by the cables.". In terms of in game performance, it scored the first rank in second best mode in *kills/pseudo deaths ratios* with 42.42%. Additionally 44.44% of subjects with stronger nausea (>= 7 on a 0 to 10 scale; n = 9) preferred Buffered pulling specifically for LizzE.

For a full comparison of the results in enjoyment and support of gameplay see Table 2.

No gender specific results could be extrapolated.

For a complete listing of all captured and extrapolated data, feel free to contact the first author.

Table 2: Means ± standard deviation of Camera Behavior Mode Enjoyment and Support of Gameplay on a 7-point Likert scale

	Enjoyment	Support of gameplay
Mode A: Fast circling	3.15 ± 1.906	3.90 ± 1.860
Mode B: Lazy circling	4.09 ± 1.627	4.15 ± 1.482
Mode C: No circling	3.64 ± 1.966	3.15 ± 1.679
Mode D: Blink circling	3.73 ± 1.825	3.61 ± 1.580
Mode E: Buffered pulling	4.48 ± 1.805	4.27 ± 1.663

A one-way repeated measures ANOVA (Laerd Statistics 2015b) was conducted to determine whether there were statistically significant differences in enjoyment between the five different modes. There were no outliers and the data was normally distributed, as assessed by boxplot and skewness and kurtosis analysis, respectively. Enjoyment scores were normally distributed for mode A with a skewness of .433 (SE = .409) and kurtosis of -1.354 (SE = .798), for mode B with a skewness of -.202 (SE = .409) and kurtosis of -.946 (SE = .798), for mode C with a skewness of .125 (SE = .409) and kurtosis of -1.185 (SE = .798), for mode D with a skewness of -.094 (SE = .409) and kurtosis of -1.118 (SE = .798) and for mode E with a skewness of -.687 (SE = .409) and kurtosis of -.679 (SE = .798). Mauchly's test of sphericity indicated that the assumption of sphericity had not been violated, $\chi^2(9) = 8.347$, $p = .50$. Enjoyment scores were statistically significantly different between the different modes, $F(4, 128) = 2.725$, $p = .032$, partial $\eta^2 = .078$ and partial $\omega^2 = .040$.

Another one-way repeated measures ANOVA (Laerd Statistics 2015b) was conducted to determine whether there were statistically significant differences in support of gameplay between the five different modes. There were no outliers and the data was normally distributed, as assessed by boxplot and skewness and kurtosis analysis, respectively. Support of gameplay scores were normally distributed for mode A with a skewness of -.138 (SE = .409) and kurtosis of -1.604 (SE = .798), for mode B with a skewness of -.645 (SE = .409) and kurtosis of -.459 (SE = .798), for mode C with a skewness of .463 (SE = .409) and kurtosis of -.674 (SE = .798), for mode D with a skewness of .248 (SE = .409) and kurtosis of -.422 (SE = .798) and for mode E with a skewness of -.160 (SE = .409) and kurtosis of -.627 (SE = .798). Mauchly's test of sphericity indicated that the assumption of sphericity had not been violated, $\chi^2(9) = 12.550$, $p = .185$. The analysis could not lead to any statistically significant changes in support for gameplay scores between the different modes, $F(4, 128) = 2.417$, $p = .052$, partial $\eta^2 = .070$ and partial $\omega^2 = .033$.

CONCLUSION

In which ways can 3rd person VR games work for a broad audience? Though this might be similar for all VR applications, to keep a broad audience playing a 3rd person VR game, it is essential to eliminate causes for nausea and simulator sickness as much as possible, while still maintaining an attractive gameplay. Utilizing a well-accepted camera behavior mode in terms of enjoyment and support of gameplay seems to be one of the most important steps. Conceiving and implementing individual viable solutions still pose significant challenges, but some approaches tested in this study clearly show great potential, whereas others seem incompatible for a broad audience in VR.

Though this study could not always elicit statistically significant quantitative data, in combination with the qualitative and observational results we extrapolated the following relevant conclusion.

When looking at the experience levels of subjects in gaming and VR, we argue that preferences to *Fast* and *Lazy circling* might be related to the already established familiarity to traditional camera techniques used in popular non-VR games like Super Mario 64, World of Warcraft and Banjo-Kazooie. Simple acclimatization with other camera behavior modes over some time might change their opinion.

The *No circling* approach, though reducing the vection effect, was clearly unusable for a level design that encourages exploration into all directions. A more linear level design like in Lucky's Tale (Hurd and Bettner 2014; Hurd and Reiland 2016) can make it a viable approach though.

In the case of *Blink circling,* nausea did not seem to be a significant problem compared to other modes, as it drastically reduces the vection effect. Furthermore, it offers a way of playing without requiring a swivel chair or physically standing up. It seems reasonable to expect better acceptance by users of this approach, once players have spent a longer time using it and were getting a better feel for when blinks will occur. As subjects were kept naive about the different camera behavior modes (except for their titles), some sort of explaining visualization and/or subtle tutorial could also help.

In this study, the *Buffered pulling* approach showed the greatest potential. The vection effect was reduced to a minimum through requiring natural movement (Riecke and Feuereissen 2012) and utilizing the buffer zone. Thus participants felt little to no nausea. Even though this is not true for all subjects, physically moving delighted the majority of them and increased their feeling of realism and presence (Lombard and Ditton 1997) in the game.

This collection of camera behavior modes is not at all exhaustive, but coming from the gathered findings of this experiment, when developing a 3rd person VR game with a freely explorable level design, we recommend implementing fine tuned versions of *Buffered pulling* (default) and *Blink circling* (optional). This gives the users the possibility of playing the game either through physical movement or more stationary on a couch for example. Adding some sort of optional *Fast* or *Lazy circling* mode for traditionalists might be alluring, but a clearly visible warning of highly possible simulator sickness would be strongly recommended.

FUTURE WORK

Though thematically a bit more distanced, investigating users' perception of visual stylistics, as Joshi et al. (2014) describes, in relation to usability of different camera behavior modes, could lead to an interesting parallel investigative lens in this field and would extend the findings in user experience of this study.

In case of *Blink circling,* the experiment showed the need to improve on supporting the orientation of users. Enhancing the user interface (UI) might be a viable solution. Adding a well designed compass-like "north indicator", for example to the outer edge of the viewing field could possibly help. Furthermore, a circle shaped, watch face like timeout indicator should improve expecting blinks and make their occurrence less random. The advantage of an UI solution is also the simplicity to make them optional for the user.

Experimenting with different fixed angle configurations (e.g. steps every 90°) for *Blink circling* could also be an interesting research direction.

Buffered pulling showed a similar demand in UI enhancement. Though, instead of indicating north, the outer edge of the UI could indicate the position of the main character instead, when this one runs out of sight. For the rare case, when the main character walked directly below the user, it might be interesting to experiment with automatically circumnavigating the main character around the user's center position or slightly pushing the VR Rig away from the character. The latter approach is likely going to increase the vection effect and might cause nausea, which would imply great caution with it.

Looking in more detail at the different session mode orders of this experiment might possibly bring up correlations to other outcomes.

Adjusting the experiment design could lead to other interesting findings. For example designing a level in the shape of a big spiral staircase could force more but also steadier camera turns. Restricting enemies to one single type would make tracking of in game performance data more uniform. A stricter more defined selection of subjects could lead to more aligned results.

Looking at and conceiving of other camera behavior modes is surely worth more research as well. For example a mode in which the user needs to manually control the circling with the second analogue stick seems logical. Furthermore, interesting results seem likely, when stepping away of the concept of algorithm only camera behavior modes. Testing modes, that utilize scripted level dependent camera angles, promises interesting results as well.

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AUTHOR BIOGRAPHY

DANIEL P. O. WIEDEMANN was born in Munich, Germany. He is currently a PhD student in the School of Media and Performing Arts at Middlesex University London. His research interest lies in the interrelationship of game design, new generation interface technologies and user experience in digital games. Before his PhD studies, he obtained a diploma in communication design and art direction at the Akademie an der Einsteinstraße U5, Munich. After that he worked for over three years as an art director experience design in an advertisement agency in Hamburg. Following this, he studied Creative Technology at Middlesex University London and obtained a Master of Science degree. During this time, he also founded FIERY THINGS, a small indie game studio. He can be contacted at d.wiedemann@mdx.ac.uk and his website can be found at http://www.daniel-wiedemann.de.